Public Joint Stock Company
ENERGOPROEKT
Kyiv Research and Development Institute

STATE-OWNED ENTERPRISE
“ENERGOATOM NATIONAL NUCLEAR ENERGY GENERATING COMPANY”—
SEPARATED SUBDIVISION “ATOMPROEKTINZHINIRING”

CONSTRUCTION OF THE CENTRAL SPENT FUEL STORAGE FACILITY FOR VVER NUCLEAR POWER PLANTS OF UKRAINE

PROJECT

VOLUME 1.1

Explanatory Note

Final

571402.201.001-P301

Chair of the Management Board	Yu. V. Malakhov
Chief Engineer	V. N. Chernavskyi
Deputy Chief Engineer	T. Yu. Baibuzenko
Project Manager	A. D. Andriushchenko
Chief Project Engineer	I. A. Dzenkiv

Public Joint Stock Company
ENERGOPROEKT
Kyiv Research and Development Institute

2016

Technical Archive 1

Volume Number	Designation	Title	Notes
1.1	571402.201.001-P301	Explanatory Note	
1.2.1	571402.201.001-P302.01	Initial Input Data. Book 1	
1.2.2	571402.201.001-P302.02	Initial Input Data. Book 2	
1.3	571402.201.001-P303	Description of the SNF Management Technology at NPP Power Units	
2	571402.201.002-GT	Master Plan and Transport	
3.1	571402.201.003-TH01	Process Design Part 1. Spent Nuclear Fuel Handling	
3.2	571402.201.003-TH02	Process Design. Part 2. Waste Management during Operation	
3.3	571402.201.003-TH03	Process Design. Part 3. Auxiliary Systems	
4.1	571402.201.004-AS01	Architectural Planning Solutions. Part 1. Explanatory Note. Architectural Solutions	
4.2.1	571402.201.004-AS02.01	Architectural Planning Solutions. Part 2. Explanatory Note. Construction Solutions. Book 1. Explanatory Note	
4.2.2	571402.201.004-AS02.02	Architectural Planning Solutions. Part 2. Explanatory Note. Construction Solutions. Book 2. Calculation Results	
4.3.1	571402.201.004-AS03.01	Architectural Planning Solutions. Part 3. Drawings. Book 1. Architectural Solutions	
4.3.2	571402.201.004-AS03.02	Architectural Planning Solutions. Part 3. Drawings. Book 2. Reinforced Concrete Structures.	
4.3.3	571402.201.004-AS03.03	Architectural Planning Solutions. Part 3. Drawings. Book 3. Metal Structures.	
5.1	571402.201.005-ETR01	Electrical Design. Part 1. Explanatory Note	
5.2	571402.201.005-ETR02	Electrical Design. Part 2. Drawings.	
6	571402.201.006-SKU	Control and Monitoring Systems	

Volume Number	Designation	Title	Notes
7	571402.201.007-OV	Heating, Ventilation, Air Conditioning	
8	571402.201.008-VK	Water Supply and Sanitation	
9	571402.201.009-PB	Fire Safety Measures	
10.1	571402.201.010-G001	Engineering and Technical Measures of Civil Protection (Civil Defense). Part 1. General Explanatory Note	
10.2	571402.201.010-GO02	Engineering and Technical Measures of Civil Protection (Civil Defense). Part 2. Civil Protection (Civil Defense) Structures	
11	571402.201.011-POS	Construction Method Statement	
12.1	571402.201.012-OVOS01	Environmental Impact Assessment. Part 1. EIA Materials	
12.2	571402.201.012-OVOS02	Environmental Impact Assessment. Part 2. Annexes	
13	571402.201.013-OSSZ	Sanitary Code Conformance Report	
14	571402.201.014-SFZ	Physical Security System	Classified
15.1.1	571402.201.015-SD01.01	Estimate Documents. Part 1. Consolidated Budget Calculation and Facility Estimates. Book 1	
15.1.2	571402.201.015-SD01.02	Estimate Documents. Part 1. Consolidated Budget Calculation and Facility Estimates. Book 2. Total Resource Statements	
15.2.1.1	571402.201.015-SD02.01.01	Estimate Documents. Part 2. Local Calculations. Book 1. Civil Design. Part 1	
15.2.1.2	571402.201.015-SD02.01.02	Estimate Documents. Part 2. Local Calculations. Book 1. Civil Design. Part 2	
15.2.1.3	571402.201.015-SD02.01.03	Estimate Documents. Part 2. Local Calculations. Book 1. Civil Design. Part 3. Bills of Quantities	
15.2.2	571402.201.015-SD02.02	Estimate Documents. Part 2. Local Calculations. Book 2. Heating, Ventilation, Air Conditioning	

Volume Number	Designation	Title	Notes
15.2.3	571402.201.015-SD02.03	Estimate Documents. Part 2. Local Calculations. Book 3. Water Supply And Sanitation	
15.2.4	571402.201.015-SD02.04	Estimate Documents. Part 2. Local Calculations. Book 4. Process Design	
15.2.5.1	571402.201.015-SD02.05.01	Estimate Documents. Part 2. Local Calculations. Book 5. Electrical Design. Part 1	
15.2.5.2	571402.201.015-SD02.05.02	Estimate Documents. Part 2. Local Calculations. Book 5. Electrical Design. Part 2	
15.2.5.3	571402.201.015-SD02.05.03	Estimate Documents. Part 2. Local Calculations. Book 5. Electrical Design. Part 3	
15.2.6	571402.201.015-SD02.06	Estimate Documents. Part 2. Local Calculations. Book 6. Instrumentation And Automation	
16	571402.201.016-PPR	Site Preparation Works	

The design has been developed in accordance with the applicable code, rules, and standards.

Chief Project Engineer I. A. Dzenkiv

Section	Position	Initials and Last Name	Signature
1, 2, 4.1, 5, 19	Chief Project Engineer	I. A. Dzenkiv	
3, 7	Chief Specialist, Unit No. 211	I. B. Levytska	
4.2, 15	Chief energy conservation and energy efficiency specialist of the Institute—developer in charge of the engineering civil design development in terms of the energy conservation (Qualification Certificate series AR No. 009590)	S. V. Holovatiuk	
6	Master Plan Group Leader, Unit No. 214	: L. V. Morskaya-Pryimachenko	1
3, 9, 12, 16	Chief Specialist for the Operation and Repair of Systems and Equipment of Thermal and Nuclear Power Plants of the Institute—developer in charge of the engineering and construction design in terms of the operating safety (Qualification Certificate series AR No. 006608)	R. A. Perepelytsia	
10	Chief Nuclear and Radiation Safety Specialist of the Institute	I V. Maidaniuk	
	Chief Specialist, OAZS Unit	V. V. Legas	

Section	Position	Initials and Last Name	Signature
11, 13	Chief Specialist of the Institute for Process Safety and Civil Protection—developer in charge of engineering and construction design in terms of fire and process safety (Qualification Certificate series AE No. 002280)	Ya. V. Nyzhnyk	
	Chief Ecology Specialist of the Institute—developer in charge of engineering and construction design terms of the assurance of the health, safety, and environment (Qualification Certificate series AR No. 006794)	D. I. Shirin	
17	Chief Design and Cost Estimation Specialist of the Institute—developer in charge of engineering and construction design in terms of the estimation documents (Qualification Certificate series AR No. 007041)	T. V. Yankovska	
18	Head of OAP	Ya. B. Shamis	

INTRODUCTION

The Central Spent Fuel Storage Facility (CSFSF) is a nuclear facility of national importance. The decision on construction and location of CSFSF was made by the Law of Ukraine "On Management of the Spent Fuel with Regard to the Location, Design and Construction of the Centralized Storage Facility for the Spent Fuel of Domestic VVER Reactors of Nuclear Power Plants" on the basis of the Investment Feasibility Study approved by Resolution of the Cabinet of Ministers of Ukraine No. 131-r of 04 February 2009. Main results of the Feasibility Study are as follows:

- The CSFSF is to be located on the site between the villages of Stara Krasnytsia, Buriakivka, Chystohalivka and Stechanka in Kyiv Region within the exclusion zone with radioactive contamination after the Chernobyl disaster;
- the storage of spent nuclear fuel to be used is a surface "dry" storage with double-barrier insulation system;
- CSFSF lifetime — 100 years;
- CSFSF capacity — 16529 SFAs, including: 12010 pcs of VVER-1000 SFAs and 4519 pcs of VVER-400;

The CSFSF is based on the technology by Holtec International (hereinafter — Holtec). Main elements of the technology:

- MPC — multi-purpose cask;
- HI-STAR 190 UA (hereinafter—HI-STAR)—a transportation cask;
- HI-STORM 190 UA (hereinafter—HI-STORM)—a storage cask;
- HI-TRAC 190 UA (hereinafter—HI-TRAC)—transfer cask;
- cask transfer facility (CTF);
- cask transfer device (CTD);
- vertical cask transporter (VCT);
- car transporter for the HI-STAR.

The design provides for the reception of HI-STARs with MPCs, transfer of the MPCs from the HI-STARs to HI-STORMs, concrete-casting of the HI-STORMs' shells, and the storage of the HI-STORMs, filled with spent nuclear fuel in the territory of the CSFSF.

The description of the SNF management technology at the power units, submitted by the technology providers, is set out in Volume 1.3. The adjustment of the technology to a specific nuclear power unit will be made under the modification designs in accordance with the current legislation in the field of nuclear energy.

This design of the CSFSF is developed on the basis of the approved Feasibility Study, Design Brief, Planning Requirements and limitations under Agreement No. 571402 of 03 October 2014 between State Enterprise "National Nuclear Energy Generating Company "Energoatom" and Public Joint Stock Company "Kyiv Research and Design Institute "Energoproekt"".

Modification 1 has been developed on the basis of Letters No. 01-46/699 of 21 April 2016, No. 01-46/761 of 28 April 2016, and No. 01-46/769 of 29 April 2016 as a result of the review of design documents by the Client.

The final version of the CSFSF design has been developed with the incorporation of results of the comprehensive state expert appraisal carried out by State-owned Enterprise Ukrderzhbudekspertyza.

1. INITIAL INPUT DATA

1.1 Initial Input Data for the Design Development

- Design Brief for the Construction of a Centralized Storage Facility for the Spent Nuclear Fuel of VVER Reactors of Nuclear Power Plants of Ukraine. Phase P (Design) and Phase R (Detailed Design Documents).
- Planning Conditions and Land Plot Development Restrictions;
- Terms of Reference for the Design of the Physical Protection System of the Central Spent Fuel Storage Facility (TZ.01/2015-SFZ.CSVIAP);
- Terms of Reference for the Development the Civil Protection (Civil Defense) Engineering and Technical Measures as a Part of Design Documents for the Project of "Construction of the Central Spent Fuel Storage Facility for VVER Reactors of Nuclear Power Plants of Ukraine";
- Technical Specifications for the Engineering Support to the Construction Project in terms of Fire and Technology Safety;

a) Technical Specifications for the connection of electrical networks of the CSFSF No. K-00-16-0403;

- Technical Solution for the connection of the outside railway to the on-site railway tracks of the CSFSF;
- Letter No. 03-46/1539 of 26 August 2016 "Railroad Grade Elevation";
- Technical Specifications No. TD-15-16490 of 10 September 2015 "Mutual Connection of the Central Spent Fuel Storage Facility of DP NAEK Energoatom as a Subscriber and MTS Ukraine Private Joint Stock Company on the KIE REC VEC Site";
- Letter No. 202/676 of 30 April 2015 "Determination of KP Vector's potential to support the CSFSF".

1.2 Initial Input Data of the HOLTEC Technology

- Central Spent Fuel Storage Facility Report. Technology Process Description, HI-2156591, Version 3;
- Accident Analysis Report, HI-2083899, Version 3;
- HI-STAR-190 and HI- STORM-190, Cask Systems' Subcriticality Report, HI-208399;
- HI-STAR-190, HI-TRAC-190 and HI-STORM-190 Radiation Protection Analysis Report, HI-2084031;
- HI-STAR-190 ML and HI-STORM-190 Confinement/Containment Assessment Report, HI-2084018;
- CSFSF Material Compatibility Assessment Report, HI-2073839;
- HI-STAR-190 and HI-STORM-190 Systems Strength Analysis Report, HI-2084001;
- HI-STAR-190, HI-TRAC-190 and HI- STORM-190 Systems Thermal Analysis Report, HI-208390;
- HI-STORM-190 Unloading and Preparation for the Completion on Site Procedure, HSP-169;
- CTF Initial Input Data (Letter from OP API No. 03-46/390 of 10 March 2016);
- VCT General View Drawing (Letter from OP API No. 03-46/55 of 16 January 2016);

- Initial Input Data for the Main Crane of the Transfer Building and the VCT (Letter from OP API No. 03-46/169 of 2 February 2016).

U.S. regulations, which had been used by Holtec for the design of the CSFSF equipment, were used in materials of the CSFSF Design for the equipment based on the Holtec technology together with Ukrainian regulatory documents. The confirmation that U.S. regulations may be used for the development of the CSFSF equipment and the analysis of its safety was provided in a document entitled “Report on Results of the Comparative Analysis of Regulatory Documents of the USA and the Relevant Requirements of Regulatory Documents of Ukraine Used for the Development of the Equipment and Systems”.

1.3 Documents Serving as the Basis for the Design

- Law of Ukraine # 4384-VI “On the Management Of Spent Fuel: Location, Design And Construction of the Centralized Storage Facility for Spent Fuel of Domestic VVER Nuclear Power Plants” following Investment Feasibility Study”—Annex Ш(25);
- Instruction of the Cabinet of Ministers of Ukraine No. 131-r of 4 February 2009 “On Endorsement of the Investment Feasibility Study of the Construction of a Central Spent Fuel Storage Facility for Domestic VVER Reactors of Nuclear Power Plants;
- Investment Feasibility Study “Construction of the Central Spent Fuel Storage Facility for the VVER Nuclear Power Plants of Ukraine (57-204.201.002.OE);
- Comprehensive (Positive) Opinion of Ukrderzhbudekspertyza State-owned Enterprise No. 84/54/2880 of 26 August 2008 “Construction of the Central Spent Fuel Storage Facility for the VVER nuclear power plants of Ukraine”

Copies of initial input data are provided in Volume 1.2.1 “Initial Input Data. Book 1”—Annexes A(1) to P(17), and Volume 1.2.2 “Initial Input Data. Book 2”—Annexes C(18) to Ю(31).

2. BRIEF DESCRIPTION OF THE CSFSF AND ITS COMPOSITION

2.1 Conformity of Design Solutions to Feasibility Study Solutions

2.1.1 Core Solutions of the Feasibility Study

DBN A.2.2-3-2004 [108] requires the design for complex facilities such as the CSFSF to be developed in three stages:

- the Investment Feasibility Study (FS);
- the Design;
- the detailed design documents.

This structure of the design process will make it possible to update solutions and indicators adopted in the Feasibility Study at the Design stage taking into account the data of the technology adopted on the basis of the tender, and the additional design documents, for instance, developed by the successful tenderer.

No major changes are expected in the Feasibility Study as a result of detailing the SNF storage technology data at the Design stage on the basis of data available at the Feasibility Study stage.

The goal of the planned activity under the Feasibility Study is to build a long-term storage facility for the SNF from VVER-1000 and VVER-440 reactors of Ukraine's nuclear power plants.

The CSFSF is to be designed on the basis of the SNF dry storage technology with the storage in an inert medium with natural air cooling. The SNF management technology considered in the Feasibility Study has been developed by Holtec (USA), and is applied at nuclear power plants in the USA.

The CSFSF within the scope of the Feasibility Study includes:

- areas for loading spent fuel assemblies (SFA) into the MPC, and for preparing HI-STAR containers for the transportation at each nuclear power plant unit with a VVER reactor;
- the transportation of HI-STAR casks with SFA from NPPs to the CSFSF;
- the reception building on the CSFSF site;
- the storage area for HI-STORM cask with SFA;
- the on-site transportation system.

Areas for loading spent fuel assemblies (SFA) into the MPC, and for preparing HI-STAR containers for the transportation are provided in reactor compartments of units of Khmelnitskyi, Rivne, and Pivdenno-Ukrayinska NPPs. Spent fuel assemblies cooled in a cooling pond for at least 5 years are loaded in the reactor service hall of a reactor compartment into an MPC; MPCs are dehydrated and dried, sealed, and filled with helium. An MPC offers two hermetic barriers to the propagation of radioactive substances from the SFA into the environment. A HI-TRAC transfer cask and a HI-STAR are used for the biological protection of the personnel in the course of transfers.

MPCs with SFA are transported from NPPs to the CSFSF using HI-STAR transportation casks designed in accordance with the USA safety requirements which will be certified in Ukraine as B(U)-type packages in accordance with requirements of PBTRM-2006 [123].

The reception building is intended for the transfer of MPC with SFA from HI-STAR transportation casks into a HI-STORM long-term storage cask. An MPC with a SFA is transferred in an isolation unit using a HI-TRAC transfer cask.

The SNF cask storage area is a passive system for the storage of HI-STORM casks that have two MPC hermetic barriers and the biological protection barrier of a HI-STORM cask.

The following buildings and structures have been identified in the course of the design of the master plan layout for the site:

- an MPC reception and transfer building, including, for instance, “dirty” workshops, the decontamination station, and the central control panel of the CSFSF;
- a HI-STORM cask storage area;
- a maintenance building with an MPC warehouse, including a shed for filling HI-STORM cask shells with concrete;
- a garage building for the parking and maintenance of the crawler transporter;
- a four-car garage with workshops for minor repairs and a decontamination station;
- a shed for the maintenance and repair of one container car and an open parking area for one escort car;
- an electrical equipment building;
- a filling station with two fuel dispensers with two underground tanks for two types of fuel;
- an administrative building with offices, an assembly hall, a canteen, and a civil defense structure;
- a motor road checkpoint;
- a railroad checkpoint;
- holding tracks for the spent fuel train consisting of five container cars, one car for a HI-TRAC transfer cask, one platform for welding and ancillary equipment, one escort car, and two buffer cars;
- a household wastewater pump station;
- a fire water pump-house;
- a fire water tank;
- storm water accumulating tanks;
- a guardhouse.

The fenced area of the site is 644 × 182 m large. Two access motor roads to the site are designed (in the north and in the south), and one access railway track (on the northern side).

The land for the CSFSF (11.72 hectares) shall be allocated within the Chernobyl NPP exclusion zone and a 6.4-km access railway track needs to be built.

A dedicated unit of NAEK Energoatom with all the necessary infrastructure and personnel will be established to support operations of the CSFSF as a nuclear installation.

The CSFSF must make it possible to prepare for storage at least 504 spent fuel assemblies from VVER-1000 reactors and 192 spent fuel assemblies from VVER-440 reactors per year. The time needed to fill the CSFS with the nuclear fuel from the NPPs currently in operation ranges from 45 to 50 years. On this basis, two major CSFSF operation periods have been identified:

- an active period (45 to 50 years) during which MPCs with spent fuel assemblies are delivered and handled, and HI-STORM casks are placed for the long-term storage;
- a passive period (50 to 55 years) during which MPCs with spent fuel assemblies are kept in metal/concrete HI-STORM casks and CSFSF systems are operated until a decision is made on the future technology of the CSFSF management in Ukraine.

A start-up facility and stages of the CSFSF construction have been identified in accordance with the design brief of the Client.

The start-up facility includes all of the above mentioned buildings and structures and all of the holding and marshaling tracks.

The cask storage area and the manufacture of HI-STORM containers will be built gradually in four stages. Foundations for HI-STORM casks in the storage area are belts designed to accommodate

32 HI-STORM casks each. The storage area includes fifteen foundations for 32 HI-STORM casks each; thus, the storage area is designed to accommodate 480 HI-STORM casks.

The total number of HI-STORM casks needed to secure the design capacity of the CSFSF is 458 casks. This number of casks will support the storage of 12010 spent fuel assemblies of VVER-1000 reactors and 4519 spent fuel assemblies of VVER-440 reactors with an assumption that 5 percent of spent fuel assemblies of VVER-1000 reactors will not be sealed hermetically resulting in the reduction of the number of spent fuel assemblies in a VVER-1000 MPC to 24 SFAs, and that 3 percent of spent fuel assemblies of VVER-440 reactors will not be sealed hermetically resulting in the reduction of the number of spent fuel assemblies in a VVER-440 MPC to 78 SFAs.

The start-up facility (Stage I) will include three foundations for 96 HI-STORM casks with 32 HI-STORM casks to be stored on each foundation. However, only 94 casks are to be built within the scope of Stage I (81 casks for VVER-1000 reactors and 13 casks for VVER-440 reactors).

Stage II will include four foundations for 128 HI-STORM casks with 32 HI-STORM casks to be stored on each foundation. However, 130 casks are to be built within the scope of Stage II.

Stage III will include four foundations for 128 HI-STORM casks with 32 HI-STORM casks to be stored on each foundation. 128 casks are to be built within the scope of Stage III.

Stage IV will include four foundations for 128 HI-STORM casks with 32 HI-STORM casks to be stored on each foundation. However, 106 casks are to be built within the scope of Stage IV.

It is assumed for the purposes of the assessment of the number of HI-STORM casks that a HI-STORM cask contains one MPC with 31 hermetically sealed spent fuel assemblies from VVER-1000 reactors or 85 hermetically sealed spent fuel assemblies from VVER-440 reactors, or 24 damaged spent fuel assemblies from VVER-1000 reactors or 78 damaged spent fuel assemblies from VVER-440 reactors.

2.1.2 Conformity of Design and Feasibility Study Solutions

The Design is the second stage of the design subject to approval. It has been developed on the basis of the Investment Feasibility Study approved in accordance with the legislation of Ukraine.

The following are the core solutions matching the solutions adopted in the Feasibility Study:

- the design is based on the technology of the dry storage of the spent nuclear fuel in an inert medium;
- the CSFSF is based on the technology offered by Holtec International;
- the list of core facilities is aligned with solutions adopted in the Feasibility Study;
- the storage facility is designed to accommodate 458 HI-STORM casks with the spent nuclear fuel. This number of casks will hold 12,010 VVER-1000 SFAs and 4,519 VVER-400 SFAs;
- the design calls for the delivery of the spent nuclear fuel to the CSFSF by rail in HI-STAR transportation casks.

The system developed by Holtec comprises the following major components:

- MPC—a multi-purpose cask;
- HI-STAR 190 UA (hereinafter—HI-STAR)—a transportation cask;
- HI-STORM 190 UA (hereinafter—HI-STORM)—a storage cask;
- HI-TRAC 190 UA (hereinafter—HI-TRAC)—a transfer cask;
- cask transfer facility (CTF);
- cask transfer device (CTD);
- vertical cask transporter (VCT);
- HI-STAR car transporter.

Revisions of the Feasibility Study solutions at the Design stage have been caused by the following circumstances:

- updates in some technical solutions offered by Holtec as storage technology providers;
- the adoption of the Law of Ukraine No. 3038-VI “On Regulation of City Development

Activities”;

- the adoption of DBN A.2.2-3:2014 “Make-up and Contents of Design Documents for the Construction of Facilities”;
- the engineering surveys carried out on the construction site;
- the optimization of design solutions;
- the implementation of fuel assemblies of new types at the Ukrainian NPPs TBC-W (LTA), TBC-W, and TBC-WR (manufactured by Westinghouse);
- the Terms of Reference for the Physical Protection System incorporating new requirements for the organization of access areas in accordance with new regulatory documents;
- new regulations adopted after the Feasibility Study endorsement.

The CSFSF is being designed after the adoption of the Law of Ukraine No. 3038-VI “On Regulation of City Development Activities”. In connection with this, the design has been developed on the basis of the following initial input data:

- the Design Brief;
- the Planning Conditions and Restrictions;
- the Technical Specifications for connections to existing systems of KP Vector;
- the Technical Specifications for the power supply.

The Planning Conditions and Restrictions have been issued for the construction of the CSFSF in the exclusion zone in accordance with Law of Ukraine # 4384-VI “On the Management Of Spent Fuel: Location, Design And Construction of the Centralized Storage Facility for Spent Fuel of Domestic VVER Nuclear Power Plants”. The CSFSF site has been approved by Law No. 4384-VI: The CSFSF is to be located on a site situated among villages of Stara Krasnytsia, Buriakivka, Chystohalivka, and Stechanka of Kyiv Province within the exclusion zone in the area subjected to the radioactive contamination as a result of the Chernobyl Disaster. According to the Planning Conditions and Restrictions, the technical solutions related to the loading in reactor compartments of power units of Khmelnitskyi, Rivne, and Pivdenno-Ukrayinska NPP, and the transportation from NPPs to the CSFSF are not covered within the scope of this design.

The adoption of new regulatory documents in Ukraine made it necessary to update design solutions in terms of:

- the assessment of the CSFSF risk consequences class and complexity category;
- the increase in the number of structures for the security guards of the facility;

- the refinement of design solutions in terms of the fire safety;
- the refinement of technical solutions in terms of the water supply and waste water disposal systems taking into consideration the condition of KP Vector's infrastructure;
- the refinement of the identification of project stages and start-up facilities in view of the construction of foundations for HI-STORM casks as a part of the PK-1 start-up facility;
- the refinement of estimation documents on the basis of new cost estimation approaches;
- the update of the grade elevation of the site as a result of the engineering survey.

2.2 Design Limits within the Scope of the CSFSF Design

The design limits within the scope of this CSFSF design have been set by:

- the Design Brief;
- the Law of Ukraine No. 3038-VI "On Regulation of City Development Activities";
- the Rules of Connection of Electrical Installations to Electrical Networks.

The general flow diagram of the CSFSF design limits within the scope of this design is presented on Figure 2.1.

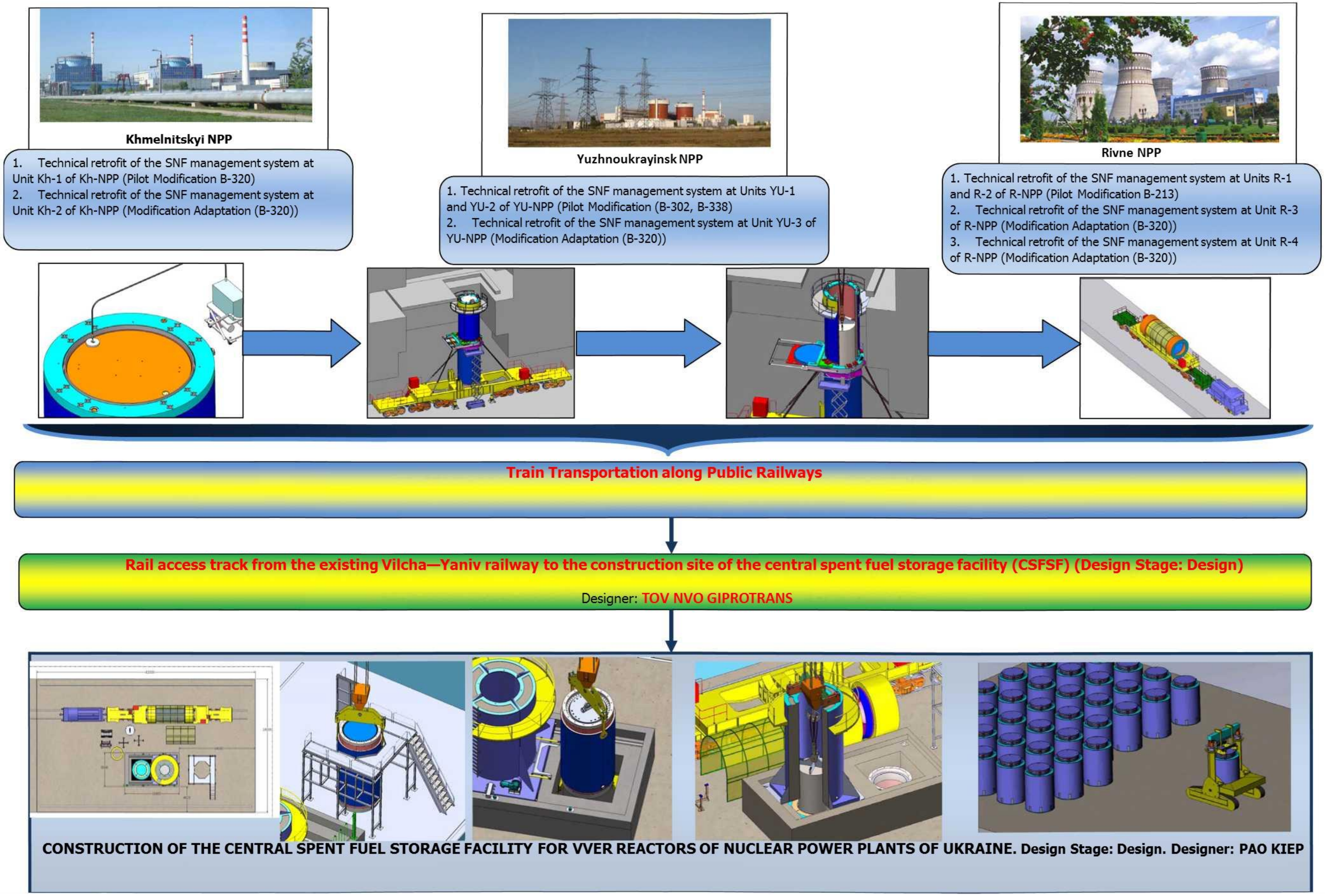

Figure 2.1. **General Flow Diagram of Design Limits**

The following is considered to be within the scope of this CSFSF design in accordance with the Design Brief:

- the reception of a special train with SNF-loaded casks, main and auxiliary equipment used at the NPP to the main marshaling track (after the radiometric check);
- the unloading of a special train in the reception building with the transfer of the MPC with SNF from transportation casks into storage casks;
- the removal of storage casks from the reception building into the storage area with a cask transporter;
- the decontamination of the main and auxiliary process equipment for the spent nuclear fuel management;
- the maintenance, testing, checking, and repair of the main and auxiliary process equipment for the spent nuclear fuel management;
- the road transport for the transportation of the process equipment for the spent nuclear fuel management, the protective clothing, the environmental monitoring.

The Law of Ukraine No. 3038-VI “On Regulation of City Development Activities” provides that:

- the design shall be developed within boundaries of the allocated land plot;
- the utility networks shall be designed up to the connection point;
- the restrictions shall be specified in Planning Conditions and Restrictions.

The connection to the electrical networks is designed in accordance with the Rules of the Connection to Electrical Networks and the Technical Specification in the Connection Point (Buriakivka SS 110/10 substation).

The connections to utility networks of KP Vector have been designed in accordance with Technical Solutions agreed upon between KP Vector and API NAEK Energoatom.

The connection to the off-site railroad is designed at the boundary of the CSFSF land allotment in accordance with the Technical Solution endorsed by TOV NVO Protrans as a designer of the off-site railroad, the general designer of the CSFSF, and API NAEK Energoatom as a Client taking into account Letter No. 03-46/1539 of 26 August 2016 “Railroad Grade Elevation”.

It has been taken into consideration in the course of the cost estimation documents development that the start-up and commissioning work on the equipment, which is only used at NPP units, will take place at the respective NPP units.

The Design Brief provides that no radioactive waste treatment will take place in the CSFSF, that the radioactive waste will be collected, assessed, and dispatched to specialized facilities within the exclusion zone. At the Design stage, the design calls for the shipment to facilities of the State-owned Specialized Enterprise Chernobyl NPP.

According to the requirements of the Exclusion Zone ARMS, the data from the ARMS of the CSFSF will be transmitted by radio.

The Design Brief does not provide for any handling of spent fuel assemblies at the CSFSF. If there is a defective MPC in the process of storage, it is to be shipped to the NPP unit for the re-loading.

The initial input data provided by Holtec have been used for the design development with regard to the equipment to be supplied by Holtec. All substantiations for the equipment, including the nuclear and radiation safety analysis, are to be developed by Holtec. The CSFSF safety assessment and analysis are presented in a Safety Analysis Report to be developed by another contractor. This activity is not included into the scope of work.

Issues of the SNF management after the completion of the target period of the storage of MPCs with spent fuel assemblies on the CSFSF site will be covered in the Concept of the Management of the Spent Nuclear Fuel from Ukrainian Nuclear Power Plants with VVER-Type Reactors to be developed by the Operator separately.

3. ENGINEERING SURVEYS DATA

The topographic and geologic surveys [1] have been undertaken by ENERGOPROEKT Institute in 2015 on the construction site for the development of the design of the Construction of a Central Spent Fuel Storage Facility of Ukraine.

The CSFSF site is located in the Chernobyl NPP area next to the Vector facility.

3.1 Topographic Survey

The comprehensive engineering topographic survey with the development of a plan to a scale of 1 to 500 has been carried out according to the geological and topographic survey program and in accordance with the Terms of Reference for the Engineering Topographic Survey.

All activities carried out are in line with requirements of regulatory documents and standards of Ukraine.

The performed survey work items are listed in Table 3.1.

Table 3.1. Survey Work

Work Items		Unit of Measurement	Quantity
1	Search for traverse stations	station	10
2	Laying reference transit traverses	km	5
3	Laying reference grade lines	km	5
4	Comprehensive engineering topographic survey in a built-up area to the scale of 1:500	ha	5.1
5	Comprehensive engineering topographic survey in a non-built-up area to the scale of 1:500	ha	30.9
6	Developing a digital terrain model (DTM)	table	5.76
7	Preliminary stake-out and horizontal/vertical tie-in of engineering geological excavations	excavation	68

The work was carried out in November 2014 to January 2015 by a topographic survey team being a part of the comprehensive survey party.

The system of coordinates is a local frame of reference to Prypiat.

The elevation system is the Baltic vertical datum.

The topographic survey team has had in its possession surveying equipment and tools of the appropriate accuracy level, such as two sets of SOKKIA electronic tacheometers, a C.A.T.^{3}+Genny^3+ Radiodetection line locator set, a LeicaDisto electronic distance gauge, and a set of Motorola radios.

The survey control was based on reference stations of the construction net under Nos. PBS1, PBS2, PBS170, PBS173, and PBS186. The network has been developed as a system of transit traverses whose points were used for the engineering leveling.

Traverse points were marked with metal rods or dowel pins.

All measurements and calculations were based on the local (“Prypiat”) frame of reference.

The survey network is a system of 12 traverses.

Angles and sides of transit traverses were measured with a Sokkia SET 230R3 No. 139993 electronic tacheometer
(subjected to the metrological control by State-owned Enterprise Ukrmetrteststandart on
30 January 2014 under No. 23-21/0000105).

Networks were balanced on a PC using CREDO DAT 4 LITE software.

Angular closing errors in transit traverses and polygons did not exceed 2Wn, where n is the number of angles per traverse.

The ultimate relative error over the traverse has not exceeded 1 in 2000.

Traverse stations Nos. 114, 115, and 118, and reference stations of the construction net Nos. PBS1, PBS2, PBS170, PBS173, and PBS186, which are accurate vertically at least at the fourth-order leveling, were used as reference geodetic stations.

The elevation network is a system of technical transit traverses over stations of the plane network.

The survey network is a system of 9 traverses.

The technical leveling has been carried out with Sokkia SET 230R3 No. 21827 electronic tacheometer (subjected to the metrological control by State-owned Enterprise Ukrmetrteststandart on 30 March 2014 under No. 23-21/0000173). The elevation network was balanced on a PC using CREDO DAT 4 LITE software.

Errors were determined using the formula of $f = \pm 50\sqrt{L}$, where L is the traverse length in km.

The topographic survey to a scale of 1 in 500 was carried out from stations of the survey network by means of tacheometry using Sokkia SET 4010 and SET 230R3 electronic tacheometers. At each station, a sketch was drawn up with all contours of buildings, structures, roads, fences, manholes, underground and overhead utilities. Underground and overhead utilities were subjected to an additional inspection with the indication of pipe diameters and elevations of gutters, well bottoms, and pipe tops. The underground and overhead utility survey results were endorsed by operating organizations and departments of GSP TsPORO of KP Vector.

Measurement results were accumulated in the built-in memory of the electronic tacheometer. After the completion of the field work, the information has been transferred to a PC for further processing via the standard interface.

The field data were subjected to the office analysis on a PC using CREDO DAT 4 LITE software suite to create a digital terrain model (DTM). At the next stage, the DTM was converted into digital and electronic topographic plans in AutoCAD for Windows software. As a result, a smooth delineation map for the replication was obtained.

Geological excavations for set out on site by means of the instrumental procedure on the basis of their positioning plan.

Excavations set out on site and marked with wooden stakes were handed over to a responsible representative of the geological unit on the basis of protocols.

After the engineering topographic survey, the horizontal and vertical tie-in of all excavations was carried out on the basis of stations of the survey basis.

A catalog of coordinates and elevations of excavations with a diagram of their positions was issued as a result of the setting out and vertical/horizontal tie-in work.

The instruments used for work were subjected to the technical control (visual examination, checks) on a daily basis prior to the commencement of measurements in the course of the field work.

The contractor in charge and the site manager controlled the compliance of the staff with regulatory requirements on a regular basis in the course of the field work. Control measurements of transit traverses of the topographic survey and surveys of underground utility networks were carried out on a selective basis after the completion of the field and office work. Measurement results obtained at the control stage confirmed that the horizontal and vertical geodetic basis was developed with the required accuracy and that errors of the landscape, contours, and utilities survey were within the acceptable range.

3.2 Geological Survey

3.2.1 Physical and Geographical Conditions of the Area

In terms of geomorphology, the CSFSF site is located in the north-eastern part of the Kyiv moraine outwash plains (Kyiv Polissia being the part of the Polissia lowlands.

The CSFSF site area is the right-bank watershed the Pripyat River valley and the left-bank watershed of the Uzh River valley, and is characterized by the undulating relief created by the water-glacial accumulation. The distance to the Pripyat River is 8 km, that to Uzh River is 18 km.

The Pripyat River is the Dnieper's right tributary. It is a typical lowland river characterized by the expressed spring flood and the relatively low summer water level. The river is 200 to 300 m wide and 3 to 8 m deep. The bottom is sandy or, sometimes, silty. Kyiv Reservoir serves as backwater at the bottom, and Pripyat River's estuary is flooded by the waters of Kyiv Reservoir. The river valley is well developed with four upland fringes. Absolute elevations of the ground within Pripyat River valley range from 105 to 135 m.

The Uzh River is the right tributary to the Pripyat River. Its valley is also well developed, and has the floodplain with three upland fringes. Absolute elevations of the ground within Uzh River valley range from 105 to 125 m.

The area under survey is located in a forest situated in the exclusion zone; a part of the area belongs to the territory of the Vector facility. The absolute elevations of the construction site are 136.98 to 140.78 m.

3.2.2 Geological Structure

In terms of tectonic structure, the investigated area is located within the Dnieper/Donetsk basin near its connection to the Ukrainian Crystal Shield; they are separated by the Dnieper fault.

The analysis of the published tectonic maps, the neo-tectonic map, the rupture anomalies map points toward the southern near-edge fault zone close to the CSFSF area, including the southern near-edge zone of Pripyat depression and the southern near-edge zone of Dnieper/Donetsk separated by the Teteriv Fault.

Currently, the CSFSF site is outside the area of the latest faults.

DBN V.1.1-12:2014 "Protection against Hazardous Geological Processes, Harmful Operating Impacts, and Fire. Construction in Seismic Areas of Ukraine" specifies the following values of the seismic rating of the investigated area at MSK-64 scale (Annex B to the DBN building code):

- the map fragment OCP-2004-A — 5 points with the seismic gap of 500 years (the seismic intensity exceedance probability for 50 years — -10 %);
- the map fragment OCP-2004-B — 5 points with the seismic gap of 1000 years (the seismic intensity exceedance probability for 50 years — 5 %);
- the map fragment OCP-2004-C — 6 points with the seismic gap of 5000 years (the seismic intensity exceedance probability for 50 years — -1 %).

The geological structure to the depth of 42.0 m is formed by the Middle Pleistocene deposits (fgRII) of fluvioglacial, lacustrine, fluvioglacial and moraine origin.

In general, these rocks are of the glacial complex of the Dnieper glaciation. The fluvioglacial deposits are sandy-clay soils. The sands are light gray, yellowish-gray to brown, small- and medium-grain, with layers of dust-like sands. In the thick sands at different depths, there are fixed lenses of clay soils. The clay soils are presented by yellowish brown sandy loam and loam. They occur as lenticles and layers generally 2 to 6 m thick. The drilled depth is 41.8 m. On the surface, the fluvioglacial sediments are covered by a layer of soil and vegetation. Near "Vector" facilities, bulk soils with the depth of 0.5 to 1.9 m occur.

The deposits of the Kyiv stratum of the Eocene (R2kv) lie at the depth of 40.0 m, the absolute altitudes of the top range from 99 to 110 m; there are marls, bluish-green and mica clays. The deposits are found everywhere, but washed out (with gaps) in some areas.

The features of the geological and hydro-geological conditions of the CSFSF construction site are determined by its affinity to the watershed plateau between the valleys of the rivers Pripyat and Uzh. Physical and mechanical properties of the soil were determined on the basis of results of laboratory tests of soils and the geophysical studies in the wells (radioisotope logging).

Archives of soil investigations carried out by the Institute at sites in the close vicinity of the CSFSF site have been analyzed for dividing the soil massive in geotechnical units and determining their physical and mechanical properties.

The geological survey resulted in the identification of 7 geotechnical units (IGEs). Their physical and mechanical properties are specified in Table 3.2.

3.2.3 Hydrogeological Conditions

The hydrogeological conditions of the CSFSF site are determined by the characteristics of aquifers and the locally developed poorly permeable sediments in the following stratigraphic sequence:

- the aquifer system of the Quaternary deposits;
- the poorly permeable deposits of the Kyiv Eocene stratum (the marl stratum);
- the aquifer system of the Eocene sediments;
- the poorly permeable deposits of marl-chalk in the upper part of the Upper Cretaceous;
- the aquifer system of the mid-Cretaceous sediments.

No.	Properties of a Geotechnical Unit (IGE)	Geological Index	Grain Size Distribution, %, mm										Uniformity Coefficient	Natural Humidity, W	Humidity at Boundary		Index of Plasticity, IP	Index of Liquidity, IL	Soil Particle Density, Ps, g per cm3	Soil Unit Weight, P, g per cm3	Soil Dry Unit Weight, pb, g per cm3	Porosity, e	Internal Friction Angle, ф⁰	Cohesion, c, kPa	Deformation Modulus, E, MPa	Design Values						Soil Class in Terms of Excavation Complexity
			Gravel		Sand					Dust		Clay			Liquid Limit, WL	Plastic Limit, WP										a=0.85			a=0.95			
			10 5	5-2	2-1	1.0 0.5	0.5 0.25	0.25 0.1	0.10 0.05	0.05 0.01	0.01 -	<0.05														ρ_{II}	φ_{II}	c_{II}	P_I	φ_I	c_{II}	
1	Top soil	eH																														8b
1a	Bulk layer — fine sand	tH																														29b
2	Fine, dense sand of heterogeneous grain-size distribution, with the water saturation from poor to rich	fgP_{II}		0.3	0.4	4.2	27.0	55.0	13.1				3.1	0.6 / 0.20					2.65	1.83 / 2.07	1.72	0.54	33	2	33	1.83 / 2.07	33	2	1.74 / 1.97	30	1	29a
3	Silty, dense sand of heterogeneous grain-size distribution, with the water saturation from poor to rich	fgP_{II}		0.2	0.4	2.7	13.9	49.3	33.5				3.3	0.09 / 0.19					2.66	1.89 / 2.06	1.73	0.54	32	4	28	1.89 / 2.06	32	4	1.80 / 1.96	29	3	29a
4	Sandy loam, solid above the groundwater level and plastic below the groundwater level	fgP_{II}		0.5	0.4	1.5	12.0	31.6	11.0	20.9	13.0	9.2		0.13 / 0.17	0.19	0.13	0.06	0.00 / 0.64	2.67	2.01 / 2.08	1.78	0.50	24	34	25	2.01 / 2.08	24	34	1.91 / 1.98	23	32	36a
5	Light stiff and plastic sandy loam	fgP_{II}		0.7	0.9	2.6	16.0	35.0	7.0	14.8	12.1	10.9		0.17	0.23	0.13	0.10	0.39	2.68	2.07	1.77	0.51	19	54	23	2.07	19	54	1.97	18	51	35a
6	Medium-grained sand of homogeneous particle-size distribution, dense, with the water saturation from poor to rich	fgP_{II}		1.9	2.7	13.3	45.8	30.1					2.7	0.04 / 0.18					2.65	1.80 / 2.04	1.73	0.53	35	2	36	1.80 / 2.04	35	2	1.71 / 1.94	32	1	29a

Note:
Soil properties above the groundwater level are specified in the numerator; soil properties below the groundwater level are specified in the denominator.

Because of certain permeability and uneven spread of the poorly permeable sediments, all the listed aquifers are interconnected and form a single hydraulic system.

The Quaternary aquifer system dominates the explored depth (42 m). During the survey period (December to January 2014, February 2015), the underground water of the Quaternary deposits aquifer system occur everywhere. This water occurs in the Mid-Pleistocene glaciofluvial sediments. The aquifer system is unconfined. In terms of salt composition, the water is mainly hydro-carbonate calcium, non-aggressive to concrete. Results of the aggressiveness analysis of the underground water are presented in Table 3.4.

In terms of protection from the surface radioactive chemical pollution, the Quaternary aquifer is vulnerable.

The depth of the groundwater layer varies from 12.2 to 19.2 m. Absolute elevations range from 120.45 to 126.95 m. The survey site is located on the watershed divide, which divides the movement of the underground water toward north and southeast. In the area of Vector facility, the perched water has been found at a depth of 3.6 to 3.7 m, which corresponds to absolute elevations of 133.45 to 133.51 m. The groundwater depth at the Vector facility ranges from 13.25 to 19.62 m according to the response of the State-owned Specialized Enterprise “Chernobylskyi Spetskombinat” to our inquiry about the groundwater situation.

The aquifer is recharged by the infiltration of the atmospheric precipitation, and discharged into the Pripyat and Uzh Rivers. In general, the hydrogeological situation is stable, there were no significant fluctuations of the water level during the survey (winter-spring).

The soil permeability (filtration factor) in the area of the CSFSF is shown in Table 3.3.

Table 3.3. Soil Permeability (Filtration Factor)

Soil Type	Soil Permeability, m/day
Silty sand in the aerated zone	1.75
Silty sand in the saturation zone	3.5
Chalky-sand in the aerated zone	3.0
Chalky-sand in the saturation zone	4.0
Medium-grain sand	15
Fluvioglacial loam	0.1
Fluvioglacial sandy loam	1.0

Temporary water table of the perched water may form in the thick deposits on top of the impermeable layers of clay soils.

No water confining strata have been found within the drilling depth. The top of the poorly permeable sediments is located at the depth of more than 40.0 m in the watershed area. The poorly permeable sediments of the Kyiv stratum (the marl stratum) are of regional distribution, they separate the Quaternary deposits aquifer from the pressure-unconfined aquifer system of the Eocene (the Buchaksko-Kanevsky) deposits.

Table 3.4. Underground Water Aggressiveness (Quaternary (Q) Aquifer)

<table>
<tr><th rowspan="2">Table No. in DSTU B V.2.6-145:2010 “Protection of Concrete and Reinforced Concrete Structures against Corrosion”</th><th rowspan="2">Indicators of aggressiveness</th><th colspan="3">Impact on concrete and reinforced concrete structures by water tightness class of concrete</th><th rowspan="2">Impact on cement-based brickwork mortar</th><th rowspan="2">Impact on asbestos cement structures</th></tr>
<tr><td>W_4</td><td>W_6</td><td>W_8</td></tr>
<tr><td rowspan="7">B.2</td><td>Bicarbonate alkalinity, mg-ecu/dm^3 (grad)</td><td>Non-aggressive</td><td>-</td><td>-</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>pH factor</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Aggressive carbon dioxide content, mg/dm^3</td><td>Non-aggressive</td><td>Non-aggressive</td><td>-</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Magnesium salt content, mg/dm^3, in terms of Mg^{2+}</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Ammonia salt content, mg/dm^3, in terms of NH_4^+</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Caustic alkali content, mg/dm^3, in terms of Na^+ and K^+</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Total content of chlorides, sulfates, nitrates, and other salts, mg/dm^3</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td rowspan="3">B.4</td><td>Portland cement under GOST V.2.7-46-96</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Portland cement under GOST V.2.7-46 with the content of C3S in clinker not more than 65%, C3A not more than 7%, C3A+C4AP not more than 22%, and portland blast furnace slag cement</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td>Sulfate resistant cements under GOST V.2.7-85-99</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td><td>Non-aggressive</td></tr>
<tr><td rowspan="3">B.5</td><td rowspan="3">Chloride content in terms of Cl^-, mg/dm^3</td><td colspan="5">Corrosivity of the liquid inorganic medium against reinforcement in reinforced concrete structures</td></tr>
<tr><td colspan="3">Immersed permanently</td><td colspan="2">Wetted intermittently</td></tr>
<tr><td colspan="3">Non-corrosive</td><td colspan="2">Mildly corrosive</td></tr>
</table>

4. FUEL, WATER, THERMAL, AND ELECTRICAL ENERGY DEMAND, ENERGY SAVING MEASURES

4.1 Fuel, Water, Thermal, and Electrical Energy Demand

4.1.1 Fuel Demand

One type of fuel (diesel fuel) is consumed at the CSFSF.

The aggregate annual fuel consumption at the CSFSF site will amount to 25 m^3 per year.

4.1.2 Water Demand

The annual water consumption of the CSFSF amounts to 3,309.5 m^3 per year.

4.1.3 Thermal Energy Demand

No thermal energy is consumed at the CSFSF.

4.1.4 Electrical Energy Demand

The annual electrical energy consumption of the CSFSF facility amounts to 4,750.98 MWh per year.

4.2 Energy Saving Measures

The Law of Ukraine “On Energy Saving” [40] is the main document in the field of the energy conservation in Ukraine. The said law defines legal, economic, social, and environmental principles of the energy savings for all enterprises, associations, and organizations in Ukraine, as well as for the citizens. The law defines “energy saving” as “organizational, scientific or practical activity focused on the sustainable use and efficient consumption of the primary and transformed energy and natural energy resources in the national economy carried out using technical, economic, and legal methods”.

Principal legislative and regulatory documents adopted in Ukraine in the field of the energy efficiency create legal, economic, organizational, and methodological foundations, set energy efficiency indicators, energy metering rules and procedures.

The CSFSF is designed so as to ensure efficient and economical energy consumption in accordance with DBN V.1.2-11-2008 [41] during a reasonable period of the regular operation subject to meeting the requirements for the internal microclimate in rooms and other conditions of the human activity.

Energy saving measures compliant with the applicable regulations [40, 42, 43] in terms of the following aspects have been designed in the course of the development of the design of the Construction of the Central Spent Fuel Storage Facility for VVER Reactors of Nuclear Power Plants of Ukraine:

- thermal engineering indicators of fencing structures and roofing;
- heating, ventilation, air conditioning, and refrigeration systems;
- electrical energy supply and consumption;
- energy metering and control.

In accordance with regulatory documents, the equipment for the development of detailed design documents will be selected taking into account its energy efficiency performance.

4.2.1 Energy Saving Measures in Process Solutions

4.2.1.1 Spent Nuclear Fuel Handling

The CSFSF is based on the technology by Holtec International (hereinafter — Holtec). This technology is currently one of the best in the world in terms of equipment and logistics. The SFA management under the Holtec technology includes:

- the reception of a car of a special cask train at the CSFSF;
- the transfer of the MPC from the HI-STAR transfer cask into the HI-STORM storage cask in the reception building;
- the placement of the HI-STORM cask with the MPC on the storage area using a transfer

vehicle;

- the long-term storage of HI-STORM casks with spent fuel assemblies.

Reception of a Train with Spent Nuclear Fuel at the CSFSF

Spent nuclear fuel is delivered from NPPs to the CSFSF by rail using a special cargo train. In accordance with the applicable regulations and technology requirements, a special train consists of:

- not more than five cars for the delivery of HI-STAR casks;
- one platform car for a HI-TRAC transfer cask;
- one platform car with auxiliary equipment;
- one escort car;
- two buffer cars.

The following equipment is used to set up a train:

- a locomotive;
- a car for the transportation of a HI-STAR cask (five cars);
- a buffer car;
- an escort car;
- a HI-TRAC transfer cask car;
- a platform car for the auxiliary equipment used at the NPP;
- a container for the auxiliary equipment.

Reception of a Car with Spent Nuclear Fuel in the Reception Building

The following equipment is suggested for use for the reception of casks with spent nuclear fuel in the reception building:

- a vertical cask transporter;
- a car for the transportation of a HI-STAR cask (five cars);
- a HI-STAR transportation and packaging set;
- a locomotive;
- a platform car for the auxiliary equipment;
- a container for the auxiliary equipment;
- a main crane in the reception building;
- auxiliary equipment.

The following equipment is used for the container car reception and reloading operations:

- an electric bridge crane with a load-lifting capacity of 185/20 tonnes;
- a HI-STAR transportation cask;
- a HI-STAR damper device (damper);
- a HI-STAR damper device lifting bar;
- a HI-STAR transportation cask lifting beam;
- a HI-STAR lifting beam storage rack;
- a HI-STAR protective case;
- a tool for screwing and unscrewing damper devices;
- a CSFSF working ground;
- multipurpose load-handling tools.

Transfer of an MPC from a HI-STAR cask into a HI-STORM cask

MPCs are transferred from a HI-STAR cask into a HI-STORM cask after the completion of the following operations:

- a HI-STAR is placed into the HI-STAR well on the CTF;
- a HI-STORM is placed into the HI-STORM well on the CTF;
- a CTD is placed above the HI-STAR well on the CTF.

The following equipment is used at the stage of the MPC transfer from a HI-STAR cask into a HI-STORM cask:

- an MPC-31 multipurpose cask;

- an MPC-85 multipurpose cask;
- an MPC lifting device;
- an MPC lifting lug;
- the cask transfer facility;
- a cask transfer device;
- MPC lifting device and lifting lug storage racks;
- a HI-STAR cap screwing/unscrewing system;
- a HI-STORM storage cask;
- a HI-STORM circular gap protector;
- multipurpose load-handling tools.

Transfer of a Loaded HI-STORM Cask and Its Placement in the Storage Area

A loaded HI-STORM cask can be placed after the completion of the following operations:

- a HI-STORM cask with a cap, temporary IAEA seals, and lifting lugs installed on the cap is placed in the central hall of the reception building in an area accessible by a vertical wheeled transfer vehicle;
- the place for the placement of the HI-STORM cask in the cask storage area has been defined;
- the passport of the HI-STORM has been prepared;
- a mobile working platform has been delivered to the HI-STORM installation location;
- an opening to fit an IAEA anchor has been prepared in the foundation slab of the storage area.

The following equipment is used at the stage of the transfer of a loaded HI-STORM cask from the reception and handling building:

- a HI-STORM storage cask;
- a HI-STORM lifting beam;
- HI-STORM lifting lugs;
- a vertical cask transporter (VCT) (transfer vehicle);
- a turning frame.

Auxiliary equipment is to be provided in accordance with the design to support the CSFSF operation and the application of the Holtec technology at NPP units in addition to the equipment to be supplied by Holtec.

A more detailed description of the equipment and SNF handling process operations is provided in Volume 3.1 “Process Design. Part 1. Spent Fuel Handling”.

The following are the major measures focused on saving energy in the course of the CSFSF operation:

- the use of modern technologies and structures that make it possible to save electrical energy and consumables during the operation with long repair intervals due to the reduction in startup peak loads (frequency regulated drives);
- the equipment design optimized for the performance and quantity in terms of the energy efficiency.

The equipment to be used at the CSFSF has optimal metal intensity and minimum energy intensity. The electrical energy is only consumed by transportation process operations carried out with the lifting equipment.

The main crane in the reception building is used to lift a loaded cask (MPC and HI-STAR), and the auxiliary equipment at the CSFSF. The crane is used for placing a loaded HI-STAR cask into upright position, its lifting from a rail platform, and its placement onto a low-profile transporter. It is also used for the transfer of a loaded MPC from a HI-STAR cask into a protective transfer tube and from a protective transfer tube into a HI-STORM cask.

The electric bridge crane with a load-lifting capacity of 185/20 tonnes is a bridge crane with electric drive, whose main hoisting winch has been engineered on the basis of a single-failure principle;

it is used for transportation and process operations with casks that contain spent nuclear fuel.

The crane is equipped with asynchronous squirrel cage electric motors controlled by variable speed drives.

The use of electric motors with variable speed drives results in the following:

- the high control accuracy;
- the electrical energy savings in the case of the variable load (the operation of an electric motor with the partial load);
- the starting torque equivalent to the maximum torque;
- the extended service life of the equipment;
- the gradual startup of the motor which reduces wear and tear;
- the controlled braking and the automated restart in the case of the power outage;
- the stabilization of the rotational speed when the load changes;
- the additional electrical energy savings due to optimizing the excitation of the electric motor;

the dynamic slowdown energy is recuperated by the drive and returned into the power supply system.

LED lights are used on the crane bridge to help reduce the electrical energy consumption.

4.2.1.2 Waste Management During Operation

During operation of the CSFSF, radioactive and non-radioactive waste is produced.

The design calls for the separate management of radioactive and non-radioactive waste, safe and reliable handling of all types of radioactive waste generated in the course of the CSFSF operation, the possibility of the mechanized loading of the radioactive waste, and the removal thereof by special vehicles for subsequent storage or treatment.

Radioactive waste management systems that ensure radioactive waste collection, categorization, and shipment to special facilities within the exclusion zone have been designed at the CSFSF to meet regulatory requirements. No long-term radioactive waste storage on the CSFSF site is planned.

The radioactive waste generated at the CSFSF are divided into liquid and solid radioactive waste.

Production waste and consumption waste are the sources of non-radioactive waste during operation of the CSFSF.

Collection, storage, and shipment of the floor drain water from the decontamination of the equipment arriving at the reception building, and the shower water from the personnel airlock are one of the main processes of handling the liquid radioactive waste. The floor drain water collection system includes piping, pumps, and tanks.

The energy saving measures within the scope of the design of LRW handling systems were focused on the selection of pumps. The design calls for using high efficiency productive pumps with a low power consumption level contributing to the attainment of high energy efficiency and reliability. Drain pumps are turned on and off by a floating switch to optimize the pump operation.

Specifications of pumps used in shower and decontamination water collection systems are presented in Table 4.1.

Table 4.1. Specifications of Pumps of the Shower Water and Decontamination Water Collection System

Model	Name	Quantity	Specifications
CM 10-1 Grundfos type	Floor drain water tank pump	2	Delivery flow rate: 10 m^3 per hour; head: 12 m; pump power: 0.65 kW; mass: 18.8 kg Flow channel: made of corrosion-resistant steel Type: centrifugal
CM 10-1 Grundfos type	Control tank pump	2	Delivery flow rate: -10 m^3 per hour; head: -12 m; pump power: 0.65 kW; mass: 18.8 kg Flow channel: made of corrosion-resistant steel

Model	Name	Quantity	Specifications
			steel Type: centrifugal
Pedrollo Dm 20 type	Drainage pump with a floating switch	5	Delivery flow rate: 1.5 m^3 per hour; head: -20 m; pump power: 0.75 kW; mass: 13.0 kg Type: submersible pump with a floating switch

A detailed description of the equipment of SNF management systems is provided in Volume 3.2 “Process Design. Part 2. Waste Management During Operation”.

4.2.1.3 Auxiliary Systems

The main CSFSF technology (SNF management) is supported by the following auxiliary systems:

- the compressed air supply system;
- the process vent system;
- the decontamination system;
- the inert gas system.

The compressed air is treated and supplied in order to supply compressed air of required quality at required pressure and flow rate to compressed-air drives of the process equipment supplied by Holtec International, and for the repair work.

The process vent system is intended to remove radioactive aerosols from the air displaced from drain waters and the shower water monitoring tank.

The decontamination system is intended for the decontamination of equipment, systems, and premises of the reception building and the garage during the operation, maintenance, repairs, and emergency management.

The inert gas system comprises two systems:

- a helium supply system;
- an argon supply system.

The helium supply system is used for operations carried out during the preparation of an MPC with the SNF in a HI-STAR cask to the power unit for re-packing, and for checking a HI-STAR cask for leaks.

The argon supply system is used in the course of welding activities in the course of manual welding.

Compressed Air Supply System

The design provides for a compressed air supply system to meet the demand of compressed air consumers.

The compressed air is supplied to consumers in the reception building from stationary compressors installed in the compressor room (116).

The following equipment is installed in the compressor room (116):

- two helical screw air-cooled compressors of GA11 type (Atlas Copco, Sweden) (1 main compressor, 1 standby compressor) with a capacity of 108.0 m^3 per hour (1.8 m^3 per minute) with a built-in 500-L air receiver each. The capacity of a single compressor is 11 kW;
- two adsorption-type dehumidifiers;
- valves and piping.

Compressors have high energy efficiency due to the modern profile of the helical screw, the use of modern materials and technologies, and a thoroughly engineered design of the compressor.

Due to the compressor’s being mounted on the air receiving tank, it is turned on periodically when the pressure in the system drops to save electrical energy. The automated compressor load control system optimizes the amount of the compressed air for the specified operating mode.

Compressed air to consumers in the maintenance building, the MPC warehouse and the garage is supplied from mobile compressors.

Depending on the type of work to be carried out, compressors are carried to a compressed air consumer.

Design calls for the application of oil-free piston compressors of LF5-10 type (Atlas Copco, Sweden) with a capacity of 29.4 m^3 per hour (0.49 m^3 per minute) with a built-in 250-L air receiver. The compressor power rating is 4.0 kW.

These compressors are compact low-noise products mounted on their frames and equipped with all connecting pipes and fittings.

Decontamination System

Decontamination methods are divided in two groups: mechanical and physical/chemical. Mechanical methods of the decontamination call for the removal of the radioactive contamination together with a layer of the contaminated material without the application of chemicals. Physical/chemical methods of the decontamination call for the removal of the radioactive contamination by dissolving it, subjecting it to chemical breakdown or emulsification.

The system is intended for the decontamination of equipment, systems, and premises of the reception building and the garage during the operation, maintenance, repairs, and emergency management.

The following equipment is designed for the decontamination of the equipment, rooms, and plastic PPE equipment:

- a mobile high-pressure washer with electric water warming;
- a wash tub in room 104 of the workshop;
- a floor scrubber;
- a vacuum cleaner for dry and wet cleaning.

Specifications of the decontamination system equipment are presented in Table 4.2.

Name	Quantity	Specifications
Dry- and wet-cleaning vacuum cleaner of Kaercher NT 70/2 Ap Me Tc type	1	Vacuum: 25.4 kPa; container capacity: 75 dm^3; power rating: 2760 W; air flow rate: 2 × 74 dm^3 per second;

Table 4.2. Specifications of the Equipment of the Decontamination System

Name	Quantity	Specifications
		voltage: 220 to 240 V; mass: 26.5 kg
Floor scrubber of Kaercher BR 40/25 C ECO Ep type	1	Effective width of brooms: 400 mm; mass: 61 kg; overall dimensions: 800 × 575 × 830 mm; capacity of the clean water tank: 25 dm^3; capacity of the dirty water tank: 25 dm^3; power rating: 1580 W; width of the suction beam: 700 m
High-pressure water-heated wash of Kaercher HDS-E 8/16-4 M24 kW type	1	Mains frequency: 50 Hz 3 phases, voltage: 380 V; capacity: 300 to 750 dm^3 per hour; maximum pressure: 17.0 MPa; maximum temperature: 80 °C; input power: 29.5 kW; net mass: 112 kg; overall dimensions (L×W×H): 940×600×740 mm; decontamination solution tank: 20 dm^3;

Modern mobile energy efficient equipment will be used for the regular wet cleaning and decontamination of rooms in the reception building. The following energy saving measures have been focused on during the development of major technical solutions for the decontamination:

- the use of high-pressure washes and wet-dry vacuum cleaners of Kaercher HP type with highly efficient electric motors;
- the minimization of the water consumption for decontamination by using modern wet-dry vacuum cleaners and high-pressure units;
- the possibility for the local water heating in a high-pressure washing unit.

Inert Gas System

The inert gas system comprises two systems:

- a helium supply system;
- an argon supply system.

<u>Helium Supply System</u>

The helium supply system is used for operations carried out during the preparation of an MPC with the SNF in a HI-STAR cask to the power unit for re-packing, and for checking a HI-STAR cask for leaks.

<u>Argon Supply System</u>

The argon supply system is used in the CSFSF for welding operations in the course of the repair work.

Filling Station

A filling station is designed to support automobile operations on the CSFSF site.

The filling station consists of one fuel dispenser and two underground fuel tanks.

The fuel dispenser of NOVA-1101.21 SB type is designed for the metering and dispensing fuel. The dispenser has a local control panel for the metered dispensing of fuel directly from the dispenser.

The fuel dispenser is equipped with standard hydraulic equipment: a single housing design with a bypass valve and a gas removal system, a volumeter with a pulse transducer, a fine filter, a return valve, and a fueling nozzle.

Diesel fuel tanks are operated in a broad range of temperatures from -50 to +50 °C. The internal zinc coating of the diesel fuel tank enhances the corrosion resistance of metal. All tanks are protected against diesel fuel leakage.

Diesel Power Plant (DPP)

The diesel power plant is designed to supply electric power without interruption in the case of electric power failures at the facility (in the stand-by mode).

The electrical equipment building accommodates the equipment of the diesel power plant (room 106).

The design provides for the installation of a single 320 kW diesel generator set. The diesel generator set is a modular open-type structure made by Caterpillar mounted on a single foundation frame.

The C13 ATAAC diesel generator sets are highly efficient and have a low fuel consumption.

The set has been designed in accordance with ISO 8528-5 requirements for the operation at a variable load, and can take 100 percent of the nominal load at a single step. The built-in control system, which includes a UPS, an automatic load transfer switch, and switchgear ensures uninterrupted power supply and stable local and remote control.

The air cooling system, the engine lubrication system, and fuel, oil, and air filters ensure the long service life. The automatic control system is capable of starting up or stopping the plant automatically, and controlling operating parameters of the engine and generator.

A detailed description of the equipment of auxiliary systems is provided in Volume 3.3 “Process Design. Part 3. Auxiliary Systems”.

4.2.2 Measures to Ensure Reasonable Choice of Materials and Designs

Requirements for the reasonable choice of materials and designs of buildings and structures are based, first of all, on the need to meet the following two conditions:

- the conformity of the chosen materials and structures with the applicable regulatory requirements for the strength and longevity of buildings and structures;
- the conformity of selected materials and structures with the building code in terms of the thermal insulation of buildings and structures to save energy while meeting sanitary hygiene requirements and maintaining optimal microclimate parameters in rooms.

The improvement of the thermal shielding of buildings and structures by means of the reasonable choice of materials and designs results in the reduction in environmental heat losses.

These measures are also considered from the point of view of the environmental protection, the sustainable use of non-renewable natural resources, and the reduction in the greenhouse effect by decreasing emissions of the carbon dioxide and other harmful substances into the atmospheric air. Core requirements for the reasonable choice of materials and designs for the thermal insulation of buildings and structures are set forth in DBN V.2.6-31:2006 [44].

4.2.3 Energy Saving Measures in Architectural and Construction Solutions

The CSFSF are has moderately continental climate with a positive moisture balance. The winter is mild; the summer is warm and humid.

In view of climate conditions, the solutions have been adopted in the design to meet the core requirement of the sustainable use of energy resources by means of the proper selection of the building thermal insulation level taking into account the efficiency of thermal energy supply and microclimate maintenance systems on the basis of the holistic approach toward viewing the building and its systems.

The thermal properties of the building walls have been chosen on the basis of regulatory requirements for specific elements of the thermal insulation of the building.

The specific values of the unit thermal energy consumption have been reduced by means of:

- a sustainable spatial and layout concept that calls for bringing individual buildings and structures in a single unit, reducing the area, and the number corners of the outside walls of the building;
- reducing the area of window openings to the minimum level meeting the natural illumination requirements;
- the arrangement of anterooms at building entrances;
- the use of efficient thermal insulation materials, and their sustainable placement in the enclosing structures;
- the enhancement of the efficiency of microclimate systems, the use of efficient heating devices and equipment, and the reasonable positioning thereof.

Thicknesses of thermal insulation layers of enclosing structures of buildings have been adopted on the basis of the thermal engineering analysis (presented in Section 15).

Design solutions for the thermal insulation of all buildings and structures will ensure the minimum acceptable thermal losses throughout the calendar year, thus meeting the regulatory requirements in the field of energy efficiency and energy conservation.

4.2.4 Energy Saving Measures in Electrical Design Solutions

4.2.4.1 Design Measures to Ensure High Quality of Electrical Energy

The transformation ratio of the balance-of-plant (BOP) transformer will be made adjustable to meet the requirements for voltage fluctuations in plant mains. Cables of power supply lines have been checked for the allowed voltage drop.

The following circuit design solutions have been adopted to reduce the impact of the voltage unsinusoidality on plant circuits and the influence of the abruptly variable load on sensitive power consuming units:

- the uninterrupted power supply units, welding and lighting networks being non-linear loads are to be connected using dedicated power supply lines connected directly busbars beyond the transformer;
- the use of the equipment with the lower level of the ultraharmonics generation.

Single-phase loads will be uniformly distributed among phases to reduce systemic asymmetry in low-voltage networks.

Quality and reliability of the power supply to control and protection systems are ensured by the application of uninterrupted power supply units.

4.2.4.2 Power Supply Technical Solutions

Electrical energy losses in transformers are a type of process losses due to specifics of physical processes occurring in the course of the electric power transmission.

Using energy efficient power transformers, where savings in the course of the operation are attained due to the low losses in the ferromagnetic core and coil, and maintaining sustainable operating mode of transformers (the optimum load factor) contribute to the reduction in electrical energy losses in transformers.

Using transformers with ferromagnetic core losses (open-circuit losses) at a level of 2.0 kW rather than transformers with losses of 2.8 kW will save about 35,000 kWh per year.

Disconnecting the garage transformer will contribute to the reduction in electrical energy losses during the period when no electrical heating is used. The electrical energy losses will be reduced by 7,500 kWh*year over the period of not using the electrical heating.

The following measures have been adopted in the electrical design to ensure sustainable and economical consumption of the electrical energy in power networks to reduce losses:

- the optimal number of power supply lines;
- the optimal cross-sectional area of cables;
- the even distribution of loads among phases;
- energy efficient lights.

Lights with energy-saving bulbs are mainly used for the electrical lighting; their electrical energy consumption is much lower than that of incandescent lamps at the same illumination level.

Using gas discharge lamps in lights is more than 4 times as efficient as using incandescent lamps.

The design provides for both natural and artificial lighting.

For the electrical energy to be consumed sustainably, the general, emergency, and outer lighting systems will be controlled separately with the division into zones and rooms.

The design provides for using equipment with low energy consumption and low losses.

4.2.5 Energy Saving Measures in Ventilation, Heating, and Air Conditioning Systems

The design calls for measures to be taken in the course of the design of heating, ventilation and air conditioning systems to ensure efficient use of energy if they are implemented and operated properly.

Building walls meet the requirements of DBN V.2.6-31:2006 [44].

The design calls for the automated control of the heat output of the electric air heater depending on the established air temperature in the rooms during the cold season in order to ensure economical consumption of the electrical energy for the supply of heat to the plenum system.

All heaters are provided with temperature controllers that make it possible to control air temperature in the relevant rooms automatically.

The design provides for the centralized reduction in the air temperature within office and amenity rooms during non-working hours by not more than 4 °C off the target temperature. The air temperature in rooms is increased to the target temperature before the working hours. Temperature sensors installed in characteristic rooms of buildings provide inputs for the automatic and remote switching of space heaters on and off in the office and amenity rooms.

The heat emitted by the operating equipment will also be recovered for heating the electrical equipment rooms and the compressor room.

4.2.6 Measures to Save Energy in Water Supply and Waste Water Disposal Systems

The following systems are designed for the CSFSF:

- water supply systems:
- utility and drinking water;
- fire water;
- hot water;
- process water;
- waste water disposal systems:
- sanitary water;
- storm water;
- process water.

Pumping equipment is the major consumer of energy resources in water supply systems.

All pumping units have temperature sensors in each coil of the electric motor; a humidity sensor wire is pulled through stator wires into the oil chamber.

The automated pump control protects pumps against the following emergency operation modes:

- the overheating of the pump electric motor;
- the ingress of moisture into the oil chamber of the pump;
- the failure of pump sensors;
- the prevention of the pump startup if the electric motor insulation resistance is too low;
- the current overload;
- the wrong sequence of phases at the control panel input (to prevent the electric motor from the reverse rotation), the low or high mains voltage, the phase shift in mains, the phase loss.

4.2.6.1 Water Supply System

At the CSFSF site, the water is supplied from the existing DN 100 off-site network (V1) that supplies process water from artesian wells to the KP Vector site. The connection will be made using DN 80 electrically welded pipes.

At the place of the connection to the existing KP Vector network, a water supply pit made of reinforced concrete elements will be built for the installation of the cutoff valves and custody meters on the pipes. The pit cover will have a lock to protect against unauthorized access.

Quality of the water supplied to the CSFSF site does not meet requirements of DSANPIN 2.2.4-171-10 [45] for drinking water. A drinking water treatment plant will be installed in the office building at the CSFSF site to ensure conformity of the water with regulatory requirements.

Drinking water consumption at the CSFSF site will be metered by a custody transfer metering unit at the inlet into each building or structure as prescribed by paragraph 13.1 of DBN V.2.5-64:2012 [46].

Hot water pipes in buildings will be thermally insulated from the source to the tap in order to optimize thermal resources.

No drinking-quality water will be used for process purposes in order to optimize the water supply system and meet the requirements of applicable regulations.

4.2.6.2 Waste Water Disposal System

All sanitary waste water from buildings and structures of the CSFSF (other than checkpoint 2) flow by gravity to the domestic waste water pump station; therefrom, it is pumped to the sanitary waste water purification works at the KP Vector site.

The design calls for the collection of the storm water by a gravity flow storm water disposal network with the subsequent separation of the contaminated and notionally clean runoff in a separating well.

Downstream of the separating well, the contaminated portion of the storm runoff is pumped by booster pump stations to the contaminated storm water accumulating tanks; after the regulation and partial settling, the water is pumped to the storm water extra purification facility with pumps installed in the accumulating tank. After the treatment, the storm runoff is discharged into the clean storm sewer of KP Vector.

The notionally clean storm runoff is subjected to extra purification at bag filters in clean storm runoff accumulating tanks, and, after the chemical analysis, is either discharged into the clean storm sewer of KP Vector or used to water the grounds and greenery. To this end, a well is designed downstream of the notionally clean tank to enable connection of portable watering units or hoses. If the content of chemicals does not meet the requirements, the runoff is pumped into contaminated storm runoff accumulation tanks. The storm runoff from the CSFSF site is discharged into the clean storm sewer of KP Vector in accordance with the technical concept for the connection to KP Vector.

Regular radiation monitoring will be carried out in all storm runoff tanks.

Custody meters are installed in pits on pipelines used for the pumping of the sanitary waste water from the CSFSF site to the KP Vector site, and for the pumping of the storm runoff into the Maryanivka River.

4.2.7 Energy Conservation in Control and Monitoring Systems

The energy conservation in control and monitoring systems is ensured by:

- the selection of equipment with the minimum power consumption;
- the use of LEDs and LED displays in alarm circuitry;
- the assurance of the quality of the electrical energy.

Power outages and permitted short-term deviations of the steady state feeding voltage and frequency should not:

- result in failures;
- cause false signals resulting self-induced movements of actuators;
- cause loss of information in the memory of system units.

There is control over presence of the feed voltage with the generation of a malfunction signal in case of the outage. Uninterrupted power supply devices are provided for the protection of the hardware in software and hardware suites.

The hardware has short-circuit protection to disconnect it from the primary power supply.

4.2.8 Resource Consumption Metering

The design provides for metering:

- process water at the CSFSF;
- water at inlets into each building;
- sanitary waste water delivered from the CSFSF to purification works on the KP Vector site;
- (notionally clean) storm water discharged into the storm water sewer of KP Vector;
- storm water delivered to purification works of the KP Vector site;
- electrical energy supplied to the CSFSF.

A liquid meter will be installed to meter sanitary waste water. VR-1 induction liquid flow rate meter made in Ukraine is suggested. It is designed to indicate and record the flow rate and the volume of conducting liquids.

VR-1 induction liquid flow rate meter consists of a primary transducer, a signal converter, and a power supply module.

The VR-1 induction liquid flow rate meter measures flow rate of conducive liquids by converting flow velocity into an electric signal directly by means of electromagnetic induction.

Specifications of VR-1 induction liquid flow rate meter:

- Nominal diameter of the primary transducer, DN, mm: 32 40;
- Upper range limit, Q_{max}, m^3 per hour: 34.6—54;
- Nominal operating pressure, MPa: 16;
- Relative flow rate and quantity measurement error, %: not more than ±1.0.

One LK-32H cold water tangential flow turbine meter per building will be installed in the office building, guardhouse, and reception building.

The LK tangential flow turbine water meter is designed to measure volume of the drinking water flowing across it at a pressure under 1.0 MPa. The meter meets the requirements of DSTU 3580-97 [47] and technical specifications TU V 33.2-22987900-012-2003.

The meter is protected against influence of the permanent magnetic field created by a permanent magnet with the surface flux density ranging from 50 to 100 mT with the total area up to 60 square cm. Parts of the meter are made of LC40S brass and resistant plastics to ensure long service life.

Specifications of LK-23H water meters:

- Nominal diameter, mm 32;
- Class and working position... BH;
- Water temperature, °C .... От 5 до 30;
- Nominal pressure, MPa... 1.0;
- Water volume flow rate,m^3 per hour:

minimum (Q_{min}) 0.12;
- transient (Q_t) 0.48;
nominal (Q_n) 6.0;
maximum (Q_{max}) 12.0;

- minimum scale spacing, m^3 .... 0.0001;
- acceptable relative error threshold, %, ... within flow rate ranges

- from Qmin (inclusive) up to Q t ±5%
- from Qt (inclusive) up to Qmax ±2%;

- sensitivity threshold, m^3/hour, not more than 0.06;
- pressure loss at Qmax, MPa, not more than .... 0.1.

KV-1.5 tangential flow turbine cold water meters are installed in the checkpoint 1 building, the maintenance building with the MPC warehouse, the concrete plant checkpoint, the garage, and the fire water pumping station.

It is designed for metering (including custody metering) water consumption and monitoring processes. The meter meets requirements of TU U 3.48 002256544-017-94.

It consists of an impeller module which is a flow chamber with an impeller and a counting mechanism tightly isolated from the impeller module. The impeller rotation is transmitted to the counter via magnetic coupling. The total amount of water passing through is indicated on a digital display and dial gauge on the instrumentation panel of the water meter. They are ISO 4064-1:1993 [48] compliant.

Specifications of a KV-1.5 water meter:

- nominal diameter DN.. 15;
- metered water working temperature range, °C .... from 5 to 40;
- metered water nominal pressure, MPa, not more than................. 1;
- minimum scale spacing, m^3 .... 0.0001;
- operating position .... H.V
- Class .... B:
  sensitivity threshold, m^3/hour, not more than............................. 0.012
  water flow rate, m^3/hour, for class B:
  ■ .... minimum, q_{min} 0.03;
  ■ .... maximum, q_{max} 3;
- class ....A:
  sensitivity threshold, m^3/hour, not more than 0,03;
  water flow rate, m^3/hour, for class A:
  ■ minimum, qmin 0,06;
  ■ maximum, qmax 3;
- acceptable relative error threshold, %, in flow rate sub-ranges:
- minimum, qmin ....±5;
- maximum, qmax for cold water ....±2;
- maximum, qmax for hot water...±3.

Local data acquisition and processing equipment (LOSOD) will be used for the electricity custody metering in 10 kV switchboard cells of PS110/10 kV Buriakivka substation feeding 10 kV lines to the 10 kV switchgear of the CSFSF in accordance with TU No. K-00-16-04-3 of 4 May 2016 issued by PAT Kyivoblenergo.

A multi-functional programmable electronic electricity meter that supports metering of active and reactive energy, automated reading and archival of measurement data, registration of the load profile by phase (including current and voltage indicators by phase), and the integration into the existing automated electricity custody metering system (ASKOE). The meter meets the requirements of DSTU IEC 60521, SOU-NMPE 40.1.35.110:2005, and carries out control and monitoring of parameters of the electricity network and the quality of the electrical energy.

4.2.9 Conclusions

Principal legislative and regulatory documents adopted in Ukraine in the field of the energy efficiency create legal, economic, organizational, and methodological foundations, set energy efficiency indicators, energy metering rules and procedures.

The CSFSF is designed so as to ensure efficient and economical energy consumption in accordance with DBN V.1.2-11-2008 [41] during a reasonable period of the regular operation subject to meeting the requirements for the internal microclimate in rooms and other conditions of the human activity.

Buildings will be built in accordance with requirements for the thermal protection (insulation) of buildings for maintaining microclimate suitable for the human activity in buildings, ensuring required reliability and longevity of structures, providing proper climate conditions for the operation of the technical equipment at a minimum consumption of the thermal energy for heating and ventilation of buildings during the heating season.

The longevity of building walls is ensured by the application of properly resistant materials (resistant to freeze, humidity, biological impact, corrosion, high temperature, temperature fluctuation cycles, and other destructive environmental impacts) with the provision of the special protection of structural elements made of insufficiently resistant materials, if necessary.

The central spent fuel storage facility for VVER reactors of the Ukrainian nuclear power plants is designed for the disposal and long-term (at least 100 years) storage of the spent nuclear fuel (SNF) from VVER reactors.

All buildings and structures at the CSFSF site have been designed on the basis of their assumed tentative service life specified in Table 19.1.

Accordingly, during this period buildings and structures must meet energy efficiency requirements with the simultaneous conformity with requirements for technologies and materials in the course of construction.

The following solutions have been adopted to ensure energy efficiency during the development of the CSFSF design:

- use of the modern economical state-of-the-art equipment;
- implementation of energy-saving technical solutions;
- optimization of the power consumption and minimization of thermal losses.

5. INFORMATION ABOUT PROJECT PHASING AND STARTUP FACILITIES

As per the Design Brief, the CSFSF is to be commissioned in a single phase with the identification of the following fifteen start-up facilities (PK):

- PK-1 includes the construction of all buildings and structures under the design, and the installation of four HI-STORM casks (3 MPC-31 and 1 MPC-85);
- PK-2 includes the installation of 33 HI-STORM casks (28 MPC-31 and 5 MPC-85);
- PK-3 includes the installation of 33 HI-STORM casks (29 MPC-31 and 4 MPC-85);
- PK-4 includes the installation of 24 HI-STORM casks (21 MPC-31 and 3 MPC-85);
- PK-5 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-6 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-7 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-8 includes the installation of 34 HI-STORM casks (26 MPC-31 and 8 MPC-85);
- PK-9 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-10 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-11 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-12 includes the installation of 32 HI-STORM casks (27 MPC-31 and 5 MPC-85);
- PK-13 includes the installation of 34 HI-STORM casks (29 MPC-31 and 5 MPC-85);
- PK-14 includes the installation of 34 HI-STORM casks (29 MPC-31 and 5 MPC-85);
- PK-15 includes the installation of 38 HI-STORM casks (34 MPC-31 and 4 MPC-85).

6. CORE SOLUTIONS AND INDICATORS OF THE MASTER PLAN OF UTILITY NETWORKS AND SERVICES

According to layout solutions, the total fenced area of the CSFSF site, including the concrete plant site, is 13.80 hectares.

The CSFSF site comprises the following buildings and structures:

- the reception building;
- the cask storage area;
- the maintenance building with an MPC warehouse:
- buildings and structures for storage and maintenance of the transfer vehicle and the fleet (a garage, a filling station);
- the electrical equipment building;
- the office building;
- the security equipment buildings and structures (a set of security structures with the guardhouse, checkpoints 1 and 2, trench shelters, physical protection equipment);
- water supply and waste water disposal buildings and structures (fire water supply pump station, fire water tanks, storm water facilities, waste water pump station, oil drain tanks (separators), etc.;
- holding and marshaling tracks for spent nuclear fuel rail cars.

The following core functional areas have been identified during the development of the layout of the CSFSF site master plan:

- a utilities area outside the southern side of the site fence near the main entrance at checkpoint 1;
- a process area in the center of the site (reception building);
- an auxiliary area in the southern and southeastern parts of the site with the maintenance building with an MPC warehouse, the HI-STORM shell storage area, the electrical equipment building;
- a warehousing area in the central and northwestern parts of the site with the SNF cask storage area;
- an area of holding and marshaling rail tracks for rail cars with the SNF along the eastern side of the site near checkpoint 2;
- a security guard facilities area in the southwestern part of the site;
- an area of auxiliary water supply and waste water disposal facilities in the southeastern part of the site;
- an area of auxiliary structures for storage and maintenance of the transfer vehicle and the fleet (a garage, a filling station) near the warehousing and process areas.

This functional zoning of the CSFSF site has been carried out on the basis of process links, sanitary and fire fighting requirements, logistics, and types of transport in accordance with paragraph 3.3 of SNIP II-89-80 [50].

The total fenced area of the CSFSF site is 13.20 hectares.

Two access roads are designed to the CSFSF site: the main one from the south and the service access from the north, as well as the rail access track on the northern side of the site. Site entrances have checkpoints and inspection platforms for cars/trucks and rail cars respectively.

The reception building is located in the center of the site; it has
a railway entrance gate and an entrance gate for the transporter that transfers HI-STORM casks with MPCs from the reception building to the storage area.
The zero absolute elevation of the reception building has been set at 139 m.

The storage area for HI-STORM casks with the SNF occupies the major portion of the CSFSF site. The cask storage area is intended for the long-term storage of MPCs in HI-STORM casks. It consists of cast-in-situ foundation slabs on which casks are placed. Between slabs, process access ways are provided for the cask transporter and other equipment, as well as for the personnel. The storage area is rectangular in shape and extends along the CSFSF site in north to south direction up to its central part. The cask storage area has its own wire-mesh fence with radiation control along perimeter and a set of the physical protection equipment. Holding and marshaling tracks run along the eastern side of the storage area.

The building with a garage for the cask transporter maintenance and repair is also designed to accommodate four cars taking into account the cask transporter traffic flow chart in the immediate vicinity of the entrance of the SNF cask storage area and the reception building. A filling station is placed south of the garage at appropriate fire-gap distances of at least 30 m from the nearest buildings and structures (Table 1 from paragraph 1.9 of VSN 01-89 Automobile Maintenance Enterprises provides that the maximum distance from a filling station to process buildings and structures shall be 18 m; that to office and amenity buildings shall be 25 m). The filling station includes two underground fuel tanks of 5 cubic meters each, and a fuel dispenser installed on an open-air concrete ground.

The storage of the at-hand reserve of empty MPCs and the maintenance of cars of the trains arriving at the CSFSF will take place in the maintenance building with the MPC warehouse located south of the reception building. The maintenance building has a rail entrance used to deliver shells of HI-STORM casks and MPC casks to the CSFSF site.

Shells of HI-STORM casks will be stored on an open-air site near the maintenance building.

The electrical equipment building and the office building are placed along the southern fence of the CSFSF site.

Security structures include a guardhouse, a drill ground, a loading area, a dog kennel, etc.; they are surrounded by a dedicated mesh fence on the southwestern side of the site near the main entrance.

Water supply and waste water disposal buildings and structures are located in the southeastern part of the CSFSF site.

Paved access roads and turning areas have been designed to ensure access of the fire-fighting machinery to all buildings and structures at the CSFSF site.

Off-site and on-site motor roads have been designed in accordance with regulatory requirements of [50, 70, 71].

On-site motor roads and access passages are 7.0 m wide at the cask transporter routes with a minimum longitudinal slope; passages for automobiles are 6.00 or 4.50 wide.

On-site railway tracks have been designed in accordance with regulatory requirements of [70, 72] for 1524 mm wide tracks, and [73] for 1520 mm wide tracks.

On-site holding and marshaling tracks are one of the main areas where nuclear fuel is handled, MPCs with SFA are delivered in HI-STAR transportation casks, HI-STORM shells are supplied, unloading operations are performed, empty cars are accumulated and held, and shunting operations are carried out.

Surface water will be drained from pavements the main access road, on-site roads and grounds via gutter inlets into the designed storm water disposal network. The drainage of motor roads is organized by means of longitudinal and transverse gradients, and the installation of curbs. On holding and marshaling railway tracks, water is drained via a system of gutters between tracks into the designed storm water disposal network.

Designs of utility networks and services of the CSFSF site provide for the following main systems:

- a power supply system (with outside earthing, security and outside lighting);

- a utility and drinking water supply system;
- a fire water supply system;
- a process water supply system;
- a sanitary waste water disposal system;
- a storm water disposal system;
- a process waste water disposal system.

Utility networks and services on the CSFSF site are designed to be laid underground.

The following are the major ways of access to the CSFSF site:

- personnel traffic ways;
- cargo and materials transportation;
- transportation of radioactive and non-radioactive waste;
- cask transporter movement;
- automobile traffic;
- rail traffic;
- traffic of the fire-fighting and emergency rescue machinery.

Access ways and various functional routes on the CSFSF site have been designed to have the least possible number of crossings. The personnel access to working places, cask transporter routes, and routes of cargo delivery by rail are separated.

Technical and economic specifications of the CSFSF site are as follows:

- the fenced area of the site is 13.20 hectares;
- the built-up area occupied by buildings and structures is 4.90 hectares;
- the area of paved motor roads, passageways, and grounds is 3.54 hectares including the pavement of the cask storage area of 2.18 hectares;
- the greenery area is 1.90 hectares;
- the building density is 37%.

Locations of buildings and structures under design, principal layout solutions, landscaping and utility network solutions, amenity and greenery solutions, and a layout of railway tracks are presented on drawings in Volume 2 “Master Plan and Transport”.

7. SOLUTIONS FOR THE ENGINEERING PROTECTION OF THE SITE, AND THE PROTECTION OF BUILDINGS AND STRUCTURES AGAINST HAZARDOUS NATURAL AND ARTIFICIAL FACTORS

Before the construction of the facility, the engineering protection of the site shall be carried out in order to prevent or mitigate negative consequences of natural or natural/artificial processes and factors with their interactions and mutual causality on the site with its buildings and structures.

The engineering protection of the site, and the protection of buildings and structures against natural and artificial factors are designed on the basis of the engineering survey science and technology report [1], and in accordance with regulatory requirements of DBN V.1.1-3-97 [2], DBN V.1.1-24-2009 [3], DBN V.1.1-25-2009 [4].

7.1 Spatial and Layout Planning Solutions for the CSFSF Site, Landscaping, Site Preparation

The CSFSF site shares a boundary with the Vector facility in the east, with a 110-kV aerial power transmission line in the west; it is bounded by a road access to the Vector facility in the south and a forest in the north.

The site is 5 km away from Shepelychy railway station, 1 km away from Buriakivka radioactive waste disposal facility, and 12 km away from Chornobyl Nuclear Power Plant.

The location of the site is shown on drawing 571402.201.002.GT-K1, Sheet 1, Situational Plan (Volume 2, “Master Plan and Transport”).

The grade elevation of the CSFSF site is 139.0.

The CSFSF comprises buildings and structures; most important of them make up dedicated functional zones.

Two access roads are designed to the CSFSF site: the main one from the south and the service access from the north, as well as the rail access track on the northern side of the site. Site entrances have checkpoints and inspection platforms for cars/trucks and rail cars respectively.

Surface water will be drained from pavements the main access road, on-site roads and grounds via gutter inlets into the designed storm water disposal network. The drainage of motor roads is organized by means of longitudinal and transverse gradients, and the installation of curbs. On holding and marshaling railway tracks, water is drained via a system of gutters between tracks into the designed storm water disposal network.

The CSFSF site is landscaped taking into account the specific features of the facility and the terrain.

At a preparatory stage, the work will be carried out to clear the construction site of the CSFSF site from forest and shrubs, and grade the area.

Greenery planting and landscaping, construction of sidewalks, and installation of external lights will be carried out to ensure proper working conditions at the site.

Sidewalks and pedestrian footpaths with a width ranging from 1.00 to 1.50 m have been designed for the pedestrian traffic on the site.

Greenery planting on the site has been designed taking into consideration locations of utilities, service lines, and zoning.

Lawn has been designed in the area free of any development or pavement; trees and bushes will be planted in areas free of utility networks. Types of trees and bushes have been chosen taking into account local climate. The soil in areas, where there is no lawn, will be graded and compacted.

The greenery planting area does not exceed 15 percent of the total area within boundaries of the design (paragraph 3.73 of SNIP II-89-80 [50]).

Other than sidewalks, landscaping elements include rest areas, benches, and litter bins.

Design of landscaping and greenery planting for the CSFSF site is presented on drawing 571402.201.002-GT-K1, sheet 6, Landscaping and Greenery Planting Plan (Volume 2, “Master Plan and Transport”).

7.2 Engineering Protection of the Site against Waterlogging and Floods

The area of the CSFSF site is slightly sloping from north to south and is characterized by elevations from 142.00 to 139.00 m in the northern part and from 138.50 to 137.00 m in the south. The grade level for the CSFSF site in accordance with the master plan is 139.00 m.

In view of this, rainfall runoff that accumulates in the neighboring area in the north will flow along the natural gradient toward the fence of the CSFSF site. CSFSF site engineering protection measures have been designed to protect the CSFSF site against floods. The design calls for arranging a strengthened drain ditch on the western side of the site designed to convey the rank overflow (a storm water runoff calculation 571402.216.022.RK00 has archived at PAO KIEP).

The drain ditch has a rectangular cross section; it is 2 m wide at the bottom with 2 m high walls strengthened with reinforced concrete. The drain ditch bottom is covered with crushed rock and strengthened with geoweb and the grade of 0.0003 m. Since the CSFSF site consists of water-permeable sandy soil with a low groundwater level, the collected runoff will be partly filtered into the soil. Reinforced concrete slabs are laid for discharging the runoff into the terrain.

No waterlogging of the site with groundwater is expected in accordance with the geological survey [1] carried out on the site in 2015 because the underground water depth ranges from 12.2 to 19.2 m.

7.2.1 Engineering Protection of the Area, Protection of Buildings and Structures against Hazardous Geological Processes

No physical, geological and hydrogeological processes and phenomena capable of affecting buildings and structures negatively have been found on the site in accordance with the geological survey [1] carried out on the site in 2015. Exogenous geological processes (EGP), such as swamp development, soil erosion, development of gullies and landslides, do not occur because of the insignificant difference between absolute elevations of the site (~2.0 m). In addition, the terrain will be graded, paved, and landscaped in the course of the construction. No changes in geological conditions are expected in the course of construction and operation of the storage facility.

Foundations of buildings and structures have been designed in accordance with regulatory requirements of DBN V.2.1-10-2009 [6] and PiN AE-5,6 [7] taking into account physical properties of the soil. Foundations of buildings and structures are supported by the stable soil footing.

During the preparatory period, the CSFSF construction site will be prepared (with more detailed information on this subjected provided in paragraph 7.1 “Recommendation on the Technology of the Main Construction and Installation Work, Volume 11, Construction Method Statement, 571402.201.011-POS); the preparation will include a number of measures, including the grading of the site (cutting and backfilling of up to 2.9 m) to the grade level of 138.800.

As a result of the site preparation, the backfilled soil compacted with the consolidation rate of 0.95 according to specifications provided below will serve as footing for foundations of some of the CSFSF buildings and structures being designed:

- density at optimal humidity of 12%: ρ = 1.74 tonnes per cubic meter;
- dry soil bulk density: ρ = 1.64 tonnes per cubic meter;
- internal friction angle: φ =30°;
- specific cohesion: C=1.9 kPa.

Local fine grained sand will be used for backfilling. Silty sands present in places to be excavated in accordance with the geological survey may only be used for backfilling in the areas free of CSFSF buildings (the silty sand must be outside the footprint of buildings under design at all times). Soil to be compacted may not contain trash, black humus soil, construction debris, organic inclusions, lumps of frozen soil.

Existing backfilled soils (IGE-1a) shall be replaced with the graded soil that meets the following physical and mechanical specifications:

- consolidation rate: 0.95;
- density at optimal humidity of 12%: ρ = 1.74 tonnes per cubic meter;
- dry soil bulk density: ρ = 1.64 tonnes per cubic meter;
- internal friction angle: φ =30°;
- specific cohesion: C=1.9 kPa.

Before foundations are built in a pit, the subsoil shall be tested for meeting the required specifications. If not, the engineering solutions will have to be reviewed.

A system of monitoring of the condition of foundations of buildings and structures will be implemented to study deformations of the subsoil under buildings and structures, to determine the condition of the subsoil, the nature of subsoil deformations, and compare actual building settling and tilt values with regulatory targets and design requirements.

No further measures are required in the field of the engineering protection of the area, protection of buildings and structures against hazardous geological processes.

7.3 Engineering Protection of the Area, Protection of Buildings and Structures against Natural/Artificial Impacts

No natural/artificial processes and phenomena capable of affecting properties of the subsoil, as well as buildings and structures negatively have been found on the site in accordance with the geological survey [1] carried out on the site in 2015, namely:

- there are no undermining areas;
- - there are no oil or gas production fields;
- - there are no water-retaining structures;
- - there is no intake of underground water directly under the site.

No changes of natural/artificial (technology-induced) nature are expected in the course of construction and operation of the storage facility.

8. OCCUPATIONAL SAFETY

DP NAEK Energoatom is going to implement and operate an occupational safety management system at the CSFSF in accordance with the Law of Ukraine “On Occupational Safety” [8], Electrical Energy Sector Companies Occupational Safety System Policy approved by Order of the Ministry of Energy and Coal Industry No. 73 of 9 February 2015. According to the above Policy, the occupational safety policy must focus on:

- maintaining good manufacturing practices;
- improving the industrial safety level by means of the ongoing technical control over the condition of the production facilities, technologies, and equipment; the use of achievements of science and technology;
- providing training, professional re-training and qualification development opportunities to personnel in the field of the occupational safety;

- social protection of workers, restitution of damage to people affected by accidents and occupational diseases.
- the Policy specifies objectives in the field of occupational safety, such as:
- the prevention of accidents;
- the reduction in the number of violations of requirements of occupational safety regulations;

- the reduction in the level of risk for the most hazardous activities;
- the reduction in the number of employees working under conditions that are not compatible with sanitary/hygiene norms;
- the obtainment of the OSMS conformity certificate under DSTU OHSAS 18001:2010 “Occupational Hygiene and Safety Management Systems. Requirements”.

Since the CSFSF does not currently have any permanent personnel, the documents for the CSFSF OSMS, including the CSFSF OSMS Policy, are expected to be completed at the stage of the commissioning activities because the permanent personnel will be appointed to the CSFSF before the commissioning of the facility.

In DP NAEK Energoatom, the occupational safety management is focused on providing safe working conditions at each working place on the basis of the following tenets:

- the priority of human life and health of the personnel;
- the responsibility of every employee for the occupational safety level at his working station;

- the reduction in the number of violations of requirements of occupational safety regulations in the course of organizing and performing work;
- the encouragement of the commitment to the good manufacturing and occupational safety practices.

The above tenets will be implemented in the CSFSF occupational safety management system.

8.1 List of Core Regulations

Table 8.1 offers a list of the core occupational safety regulations applied by DP NAEK Energoatom and its separated subdivisions.

Document Name	**Designation**
Law of Ukraine “On Occupational Safety”	
Main Radiation Safety Assurance Rules of Ukraine	OSPU DSP 6 177-2005-09-02
Radiation Safety Standards of Ukraine. State Health Standards (NRBU-97)	DHN 6.6.1-6.5.001-98
Radiation Safety Standards of Ukraine. Amendment: Radiological Protection against Potential Exposures. State Health Standards (NRBU-97/D2000)	DHN 6.6.1-6.5.061-2000
Occupational Noise, Ultrasound and Infrasound Sanitary Standards	DSN 3.3.6.037-99.
Hazardous and Harmful Process Factors.	GOST 12.0.003-74*
Classification	(ST SEV 790-77) *(COMECON standard)*
Production Premises Microclimate Sanitary Standards	DSN 3.3.6.042-99.
Electrical Installation Rules	PUE 2009 in 2011 version
General Sanitary and Health Requirements for the Working Zone Air	GOST 12.1.005-88 SSBT
Alternating Current Switchgears and 330, 400, 500, and 750 kV Aerial Power Transmission Lines. Rules of Protection of the Maintenance Personnel against the Electromagnetic Field Impact	GKD 34.03.601-95
Rules of Occupational Safety for the Operation of the Thermomechanical Equipment of Power Plants, Heating Networks, and Installations Using Thermal Energy	NPAOP 0.00-1.69-13
Rules of Installation and Operation of Fire Alarm and Evacuation Management Systems in Buildings and Structures	NAPB A.01.003-2009
Natural and Artificial Lighting	DBN V.2.5-28:2006
Rules of the Safe Operation of Electrical Installations of Consumers	NAOP 40.1-1.21-98
Rules of Occupational Safety of Working at Height	NPAOP 0.00-1.15-07
Sanitary Rules of the Organization of Processes and Hygiene Requirements for the Process Equipment	SP 1042-73 (DNAOP 0.03-1.07-73)
Rules of Installation and Safe Operation of Pressure Vessels	NPAOP 0.00-1.07-94
Rules of Fire Safety in Ukraine	NAPB A.01.001-2014
DSANPIN. Health Categorization of Occupational Activities in Terms of Harmfulness and Hazard of the Process Environment Factors, Working Process Difficulty and Stress Level as approved by Order of the Ministry of Health of Ukraine No. 248 of 8 April 2014	-
Protective Electrical Safety Measures in Electrical Installations of Buildings and Structures	DBN V.2.5-27-2006
Rules of Safe Work with Electrical Power Tools and Accessories	NPAOP 0.00-1.30-01
Rules of Special Training and Education in the Technical Operation of Electrical Energy Sector Facilities	GKD 34.12.102-2004
Model Occupational Safety Instruction for the Work in Confined	GKD 34.03.804-97

Document Name	Designation
Spaces	
Model Charter of the Occupational Safety Function	NPAOP 0.00-4.21-04
Model Procedure of Occupational Safety Training and Knowledge Testing	NPAOP 0.00-4.12-05
Procedure of Investigation and Record-keeping of Occupational Accidents, Occupational Diseases, and Process Emergencies	-
Procedure of the Provision of Special Clothing and Footwear, and Other Personal Protection Equipment to the Personnel	NPAOP 0.00-4.01-08
List of Elevated Hazard Work Activities	NPAOP 0.00-2.01-05
Procedure of Medical Examinations of the Personnel of Certain Categories approved by Order of the Ministry of Health of Ukraine No. 246 of 21 May 2007	-

8.2 Process Safety Measures

The following processes will take place in the course of the operation of the CSFSF:

- monitoring and maintenance of HI-STORM storage casks;
- operation and maintenance of the thermomechanical and electrical equipment, and instrumentation equipment for keeping the facility safe;
- operation and maintenance of buildings and structures of the CSFSF;
- operation and maintenance (assessment) of load-lifting machinery;
- transportation and process operations that involve handling of spent nuclear fuel transportation and storage casks;
- operation of road and rail vehicles.

The production process safety is ensured by implementing the following organizational and technical measures:

- equipment, buildings, and structures shall be operated in strict conformity with operating instructions and requirements of the organizational and instructive documents of DP NAEK Energoatom, regulations, and requirements of the documentation of manufacturers;
- assessment of working places (in terms of working conditions) for the conformity with requirements of regulations and documents of DP NAEK Energoatom aimed at detecting and eliminating conditions that can result in the deterioration of the health of personnel (Resolution of the Cabinet of Ministers of Ukraine No. 442 of 1 August 1992 “Procedure of Assessment of Working Places for Working Conditions”);
- monitoring of the technical condition of equipment, buildings and structures in accordance with requirements, instructions, and operating regulations and documents of DP NAEK Energoatom;
- control over the compliance of the personnel with requirements of occupational and labor safety regulations and documents of DP NAEK Energoatom;
- organization of occupational safety training and knowledge tests and briefings of personnel in accordance with requirements of NPAOP 0.00-4.12-05 [9] and PL-S.0.26.029-05 [10].
- provision of special clothing, PPE and PRPE to the personnel in accordance with the OSPU [12] and NPAOP 0.00-4.01-08 [13];

use of safety signage and posters in accordance with requirements of the Technical Regulation for Occupational Safety and Health Signage approved by Resolution of the Cabinet of Ministers of Ukraine No. 1262 of 25 January 2007.

8.3 Toxic, Fire/Explosion Safety Specifications of Materials, Semi-finished Products, Process Waste, and Control over Safety Requirements

There are no toxic or fire/explosion-hazardous semi-finished products or process waste in the CSFSF.

Design calls for the application of decontaminants permitted in Ukraine, having sanitary/health certificates, and efficient in different conditions, to decontaminate rooms in the reception building, the equipment, and the special vehicles. Decontaminants listed in Table 8.2 will be used.

Table 8.2. **List and Specifications of Decontaminants**

Agent Name	**Agent Description**	**Agent Purpose**	**Contamination Type**	**Hazard Class under GOST 12.1.005-88**
FRES-20	Fire-safe freon (halocarbon compound) and ethyl alcohol blend Non-toxic	Decontamination of electrical equipment surfaces		-
Selan-3	Water solution of polyvinyl alcohol and glycerin with surfactants and sequestrants. Fire and explosion safe. Non-toxic	Dry decontamination of various surfaces of rooms and equipment (painted and non-painted carbon and corrosion resistant steel surfaces; concrete and plastered surfaces painted with decontaminable chemical-resisting enamel paints; organic and silicate glass surfaces; surfaces of self-leveling floors on the basis of epoxy and polyester resins.	Removal of alpha and beta-active contaminations at the ambient air temperature above zero and relative humidity up to 90 percent	-
Selan-4	Water solution of polyvinyl alcohol and glycerin with surfactants and sequestrants. Fire and explosion safe. Non-toxic	Dry decontamination of corroded metal surfaces	Removal of strongly fixed alpha- and beta-active contaminations at the ambient air temperature in the range from -15 °C to +40 °C, and relative humidity up to 90 percent	-

Agent Name	Agent Description	Agent Purpose	Contamination Type	Hazard Class under GOST 12.1.005-88
Baryer	Powder blend of surfactants, leachable and acidic additives. Fire and explosion safe. Non-toxic	Decontamination of metal building structures, equipment, and vehicles.		-

Other agents listed hereinbelow may also be used for the decontamination.

Fon and Raddez are aerosol foam standalone decontaminants. They are available in spray cans making it possible to decontaminate directly at a working place. These decontaminants are supplied as 0.5 dm^3 spray cans in corrugated boxes.

Fon-P (TU 6900-002-73039369-2004) decontaminant is used for the decontamination of various surfaces. It is a flavored solution of surfactants in an ethanol/water blend with a propellant, sequestrants, and organic acids.

Fon-К (TU 6900-003-73039369-2004) is used for the decontamination of the human skin. It is a flavored solution of surfactants in an ethanol/water blend with a propellant, sequestrants, and organic acids.

Fon-E (TU 6900-001-73039369-2004) is used to decontaminate electrical equipment and assembled devices. It is a saturated alcohol solution with special additives.

Raddez-P (TU 95 2700-98) is used to decontaminate metal and polymer surfaces. It is a flavored solution of surfactants in an ethanol/water blend with a propellant, sequestrants, and organic acids.

Raddez-D (TU 95 2701-98) is used for the decontamination of the human skin. It is a flavored solution of surfactants in an ethanol/water blend with a propellant, sequestrants, and organic acids.

These decontaminants are non-toxic, fire and explosion-safe.

Fire and explosion-hazardous materials are used at the filling station and in the garage; their specifications are specified in Table 8.3.

Table 8.3. Specifications of Fire and Explosion-hazardous Materials

Substance Description	**Fire or Explosion Hazard**	**Hazard Class under GOST 12.1.007-76**
Diesel fuel	Diesel fuel is a flammable liquid with the autoignition temperature of 300 °C (**L-branded** summer fuel) or 310 °C (**Z-branded** winter fuel). Ignition ranges are as follows: 69 to 119 °C (for **L-branded** summer fuel) and 62 to 105 °C (for **Z-branded** winter fuel.	IV
Engine oil	Engine oils are a flammable viscous liquid with a flash point in the range of 165 to 235 °C, an autoignition range of 300 to 350 °C; upper ignition limits of 193 to 225 °C and lower ignition limits of 154 to 187 °C.	IV

Control over compliance with safety requirements will be exercised by the nuclear, radiation and occupational safety inspector, and the engineer in charge of occupational safety in a process unit in accordance with the Electrical Energy Sector Companies Occupational Safety System Policy.

8.4 Description of Processing Areas, Calculation or Substantiation of Explosion and Fire Hazard Categories or PBE Classes

Categories of CSFSF rooms in terms of the fire and explosion hazard level have been determined in accordance with NAPB B.03.002-2007 [14] and listed in Table 8.4.

Table 8.4. Categories of CSFSF Rooms in Terms of Fire and Explosion Hazard

Room Number	**Room Name**	**Area, square meters**	**Explosion/Fire and Fire Hazard Category**
Reception building			
114	Central Room (transport-technological operations room)	953.5	Д(E)
103	Water metering room	18.8	Д(E)
104	Machine repair shop	48.2	Г(D)
105	Room for cleaning and decontamination machinery	9.1	Д(E)
106	Decontamination chemicals store room	9.6	Д(E)
107	Radiochemical laboratory	33.8	Д(E)
109	Floor drain tanks room	46.7	Д(E)
110	Monitoring tank room	28.1	Д(E)
111	Special sewage pumps room	29.2	Д(E)
116	Compressor room	24.8	Д(E)
117	BOP 0.4 kV switchgear room	87.4	B(C)
118	Plenum ventilation center	34.8	Д(E)
125	Tools store room	7.3	Д(E)
202	TLD dosimetry laboratory	17.0	Д(E)
203	Electrical switchboard room	8.3	B(C)
303	Control and management systems server room	32.5	Д(E)
304	Server room	36.4	Д(E)
305	Telecommunications room	30.1	Д(E)
306	CSFSF centralized control and management systems room	48.5	Д(E)
321	Instrumentation workshop	36.8	Д(E)
401	Plenum ventilation center	95.5	Д(E)
402	Exhaust ventilation center (exclusion area)	106.3	Д(E)
403	Exhaust ventilation center (normally occupied area)	23.5	Д(E)
406	Radiation monitoring system room	16.6	Д(E)
Maintenance building with an MPC warehouse			
101	Equipment maintenance and warehousing room	1300.0	Д(E)
102	Mechanical workshop	74.25	Г(D)

Room Number	Room Name	Area, square meters	Explosion/Fire and Fire Hazard Category
103	Concrete laboratory	43.81	Д(E)
104	Electrical switchboard room	10.52	B(C)
105	Electrical workshop	24.71	Д(E)
115	Spare parts store room	16.05	Д(E)
203	Plenum ventilation chamber	23.47	Д(E)
204	Exhaust ventilation chamber	22.5	Д(E)
205	Spare parts store room	22.48	Д(E)
209	Workshop (ventilation, water supply and waste water disposal systems)	17.74	Д(E)
Office building			
003	Filter and ventilation room	23.27	Д(E)
016	Drinking water preparation plant room	82.32	Д(E)
218	Ventilation chamber	17.65	Д(E)
Electrical equipment building			
101	Water metering room	3.65	Д(E)
102	BOP 0.4 kV switchgear	86.3	B(C)
103	BOP 10 kV switchgear	49.5	B(C)
104	Ventilation room	31.6	Д(E)
106	Diesel power plant room	49.8	B(C), F-I
Garage			
101	Covered parking lot	190.8	B(C), F-IIa
102	Maintenance and repair section	102.6	B(C), F-IIa
103	Washing and decontamination room	83.8	B(C), F-IIa
104	Mechanical workshop	42.8	Г(D)
105	Ventilation chamber	35.2	Д(E)
106	Ventilation chamber	17.1	Д(E)
107	Store room	17.1	B(C), F-I
111	Garage for the transfer vehicle	216.0	B(C), F-IIa
112	BOP 0.4 kV switchgear	102.6	B(C)
Fire water supply pump station			
1	Motor room at -2.500	74.8	Д(E)
1	Motor room at 0.000	20.8	Д(E)
Guardhouse			
003	Ventilation chamber	19.7	Д(E)
107	Armory	23.65	B(C), F-IIa
121	Garage	71.68	B(C), F-IIa
123	Study materials workshop and store room	11.23	Д(E)
221	Ventilation chamber	11.06	B(C), F-IIa
222	Ventilation chamber	19.35	Д(E)

8.5 Determination of the energy potential of explosion hazardous units, radiuses of potential destruction zones, actions to protect the personnel from injuries, and to arrange safe evacuation of workers in case of possible emergencies and fires

There are no explosion hazardous units at CSFSF.

In case of emergency response actions, operating personnel shall follow the guidelines on elimination of emergencies in the operation of the systems and equipment. A package of guidelines on elimination of emergencies at CSFSF pursuant to the practice utilized by SE NNEGC Energoatom will cover the entire list of operational occurrences and emergencies anticipated in the project. Emergency elimination guidelines identify the procedure of the personnel actions to ensure safety in case of emergencies.

Personnel evacuation measures, gathering locations and escape routes in case of emergency will be determined in the Emergency Plan.

For protecting the personnel in evacuation, pursuant to requirements set in EIC [16], Chapter 5 of the Ukrainian Building Code Document DBN V.1.1-7-2002 [17], foresees the following measures:

- evacuation is anticipated only via emergency exits;
- clear height and width of the emergency exits (doors) shall be not less than 2.0 m, and the width - 0.8 m;
- doors of the emergency exits and doors on escape routes open in the direction of the people's escape;
- doors of the emergency exits from the floor corridors and stairwells have no locks preventing their free opening from the inside without key;
- corridors are free from equipment and utilities protruding from the wall pane at a height under 2 m, and have no pipelines carrying flammable substances;
- current conducting parts of electric installations, as well as conductors of any purpose, satisfy requirements of the EIC [16] regarding their maximum permissible heating at all possible modes of the electric installation operation.

Distance from the most remote workplace to the nearest emergency exit does not exceed 20-30 m in the administrative and amenity buildings and premises and 50 m in the production buildings.

Floors on the escape routes are arranged without level differences and edges.

Walls and ceilings on escape routes are finished in accordance with requirements set in par.5.24 of DBN V.1.1-7-2002 [17] with use of materials having fire hazard index not higher than:

- G2, B2, D2, T2 - for wall and ceiling finish in the corridors;
- V2, RP2, D2, T2 - for flooring of the corridors.

Emergency exit signs are anticipated with built-in rechargeable batteries.

If the working lighting is off for any reasons, emergency (safety) lighting remains operational and enables to continue work at a permissible reduced illumination. Safety lighting is anticipated in premises without natural light, in main process areas, ventilation chambers, in MV SG premises, as well as in control panels.

In case of failure of the working lighting, safety lighting shall create on the working surfaces in serviceable production premises the lowest illumination in 5%, rated for the working illumination from the total one, but not less than 2 lx.

Escape lighting is arranged on escape routes, in places dangerous for pedestrian traffic, in premises where leaving from the premise in case of emergency failure of the working lighting is connected with the injury risk in case the production equipment remains in operation. LED Exit signs are anticipated with built-in rechargeable baterries ensuring at least 1 hour of offline operation (par.6.1.23, EIC [16]). Escape lighting shall ensure the lowest illumination of 1 lx on the floor of main passages and on the steps of the stairs in the premises (par.6.11, EIC [16]).

8.6 Data on illumination of workplaces, noise, vibration, methods of extraction and neutralization of wastes with hazardous properties

Electrical lighting is executed in accordance with Chapter 6, EIC [16] and par.4, DBN V.2.5-28-2006 [19].

Anticipated illumination by premises:

- corridors - 50-100 lx;
- clean room - 200 lx;
- stairs - 100 lx;
- electric premises, control and measurement instrumentation - 200 lx;
- local switchboards - 300 lx;
- ventilator premises - 100 lx;
- area with casks (reception, rehandling) - 600 lx;
- reloading of casks, treatment of assemblies, monitoring of casks, technical maintenance - 300-500 lx;
- pump, diesel and compressor rooms - 200 lx;
- radiation monitoring rooms – 150 lx
- office space - 300 lx;
- access control hall - 200 lx;
- water closet rooms - 100 lx.

Light sources are mainly luminaires with luminescent and mercury (sodium) lamps with power factors not below 0.9 and 0.85 respectively (par.6.2.1, EIC [16]).

Combinated lighting - general and local - is anticipated in the premises. In case of the local lighting, luminaires are installed at workplaces in direct vicinity of the working zone.

Required illumination in the premises is ensured by working and emergency lighting lamps thus ensuring required conditions both for normal operation and for cases of emergency failure of the main (working) power supply sources.

Storage area for the casks is lit by floodlight towers combined with lightning rods, searchlights with sodium lamps. This ensures 30 lx illumination for performance of works during the dark hours, and 2 lx for illumination of railway tracks.

Power supply for the working lighting of the storage area for the casks and of the railway tracks is fed from the reception building. The control is remote from the reception building (each tower separately) and local, from the lighting assembly installed at the entry to the cask storage area.

For security lighting along the roads, luminaires with sodium lamps are installed on reinforced concrete poles. The poles are installed at a distance of 1 m from the internal fence (in the exclusion zone) with the interval not more than 20 m. In this case, it will ensure illumination across the width of the exclusion zone of at least 15 lx during the dark hours (horizontal at the ground level and vertical on the fence pane).

Security lighting of the cask storage area is arranged from floodlight towers combined with lightning rods, searchlights with sodium lamps. In this case, it will ensure illumination of at least 15 lx during the dark hours.

Source of the noise that has impact on the environment is dry type 10/0.4kV 1000kVA transformers installed in separate premises:

- reception building - two 1000kVA transformers;
- garage for 4 cars and cargo carrier - one transformer, 1000kVA;
- electrical equipment building - two transformers, 1000kVA.

Noise characteristics of the transformers are given in Table 8.5.

Table 8.5 - **Noise characteristics of the transformers**

Measured value:	Transformer noise level 1000 kVA
Average acoustic power level Lw(A), db(A)	73
Average acoustic pressure level (at 1 m distance) Lp(A), dB(A)	59

Noise generated by the transformer doesn’t exceeds 80 dB and requires no special protective actions.

There are no vibration sources leading to exceedance of the standard thresholds in premises with permanent personnel presence.

There are no wastes with hazardous properties at CSFSF.

During operation of CSFSF, LRW and SRW may form, which handling system is described below.

Drain water storage and transportation system

Drain water from flood traps of the active drains are fed under gravity to the sump of the premise with drain water tanks. Flood traps are arranged in every premise where decontamination is anticipated. From the drain sump drain waters are pumped into one of the drain water tanks. The plan anticipates two tanks with the capacity of 4 m^3 each - one is operational, and one is backup. The tanks are connected by the joint manifold. Switching of the drain water arrival from one tank to another is performed by the operator according to the signal of the medium upper level in the receiver tank.

For pumping the accumulated LRW out to a vehicle - 5 m^3 tank truck for removal of LRW at Chernobyl NPP two pumps of the drain water tank are anticipated (one is operational and one is backup), each with the throughput of 12.5 m^3/hour. Pressure conduit from the pump room leads to the central hall to which the motor vehicle access is ensured. Flowmeter is installed on the pump heads to control LRW volume pumped into the vehicle.

In order to assess the activity of the LRW accumulated in the reception tank, stationary control of the drain water activity is performed. According to the results of such control, the following is assessed actions to ensure radiation safety of the personnel during sampling and to coordinate reception of drain water at Chernobyl NPP.

After the receiver tank is full, personnel will take samples, for which purpose the design provides for the sampling cupboard located in the laboratory. The laboratory analyses the tank medium for the isotopic composition and activity. Based on the control results, the personnel compiles the LRW batch passport and calls a vehicle from the Chernobyl NPP to transport LRW to the Chernobyl NPP.

For control of the LRW handling system local console, on-the-spot control, and control from the central control and monitor panel are anticipated. On the central control and monitor panel most important system parameters (level in the drain water tanks, tank medium activity, status of the pumps operation (on/off), and readings of the flowmeter) are displayed.

Shower water storage and transportation system

The system is intended for reception, control and transportation of the water from showers and wash hand basins of the contamination control zone to the shower water control tanks. The system comprises manifolds, pipelines to connect manifolds and individual sources, as well as tanks and pumps of the shower water tanks.

The system is designed to receive up to 4 m3/day of the shower water. The water is low-activity LRW or non-radioactive at all.

Liquid wastes generated at CSFSF are considered radioactive if they satisfy the criterium of specific activity. With that said, it is considered that main radionuclides are ^{137}Cs, ^{90}Sr. Therefore, shower room water will refer to radioactive if their specific activity by ^{137}Cs exceeds 10^7 Bq/m^3, and that by ^{90}Sr – 10^6 Bq/m^3.

At normal operation, water from the shower rooms and wash hand basins is fed under gravity to the control tanks (2 pcs.) of shower waters. One of these tanks is used as a receiver tank and the second is used as a feeder tank. The system provides for 2 pumps: main and backup.

For the case of accidental spill of the water, there is a sump arranged, with the depth of 1 m and a drainage pump. Drain water can be pumped out into any of the control tanks.

After one of the tanks is full, the personnel will switch discharge from the system to the neighboring tank.

Samples are taken from the filled tank. The laboratory performs analysis of the specific activity of the samples. If the specific activity of the water in the tank by ^{137}Cs does not exceed 10^6 Bq/m^3, and by ^{90}Sr – 10^5 Bq/m^3, then the water from the control tanks is discharged under gravity to the domestic sewage system. If the specific activity exceeds the indicated values, then the water will be transported for treatment to the Chernobyl NPP. Information on the results of the sample analysis by the lab technician is recorded in the LRW control and accounting system.

If the water is radioactively contaminated, the shift supervisor approves its transportation to the Chernobyl NPP. After the reception is approved, LRW batch passport will be prepared.

Solid radioactive waste storage and transportation system

Low-activity and medium-activity SRW handling system is intended for handling of the solid radioactive wastes formed at the normal operation, at violations of the normal operation, and at design basis accidents at CSFSF.

SRW generated at CSFSF are considered radioactive if they satisfy the criterium of specific activity. Classification of SRW categories by the specific activity criterium is given in Table 8.6.

Table 8.6 - **Classification of SRW categories by the specific activity**

RW categories		Range of SRW specific activity values, kBq/kg	
		Alpha radionuclides Group 2	**Beta, gamma radionuclides Group 3**
1	Low-level radioactive	$>10^0<10^2$	$>10^1<10^3$
2	Medium-level	$\geq 10^2<10^6$	$\geq 10^3<10^7$

During the operation, solid radioactive wastes may form at performance of the scheduled works on radiation situation control, at decontamination, at equipment maintenance and repair and at replacement of the active ventilation filters.

SRW are:

- materials utilized at the maintenance and repair (M&R);
- failed (used) and irreparable equipment;
- used protective clothing that refers to radioactive wastes by the contamination criterium and is not subject to decontamination;
- spent PPE;
- wipe rags, wiping materials, swabs;
- spent active ventilation filters;
- contruction wastes.

Handling of low- and medium-activity SRW is a set of technological operations, which includes:

- collection in the generation locations, radiation control and packing in the primary packaging (PE bags);
- delivery of the primary packages with SRW to the SRW collection and temporary storage area;
- KT-0.2a cask identification in the RW control and accounting system by the RW handling operator;
- packing of the primary packages into KT-0.2a cask under control of the dosimetrist and RW handling operator;
- entry of the information about the wastes into in the RW control and accounting system;
- closing of the KT-0.2a cask cap;
- radiation control of the surface contamination of KT-0.2a cask and local decontamination if required;
- completion of a SRW batch passport at the control station of the RW control and accounting system;
- loading of the transfer cask onto the vehicle and removal to the Chernobyl NPP.

At each SRW collection point there are KT-0.2a casks installed, with the inserted primary plastic, PE package, and craft bags. Depending on the wastes activity, the casks are painted as follows:

- for 1 category SRW - white color;
- for 2 category SRW - blue color.

In addition to stationary SRW collection areas, the provision is made for temporary - for the duration of the equipment repair - collection areas, where casks for different SRW categories are placed. Quantity of the casks and their types are determined during preparation for the repair and planning of the works. Temporary collection areas are arranged in the premises where repair is performed, in direct vicinity of the work locations.

The following shall be used for transporting Group I and II SRW from CSFSF to the Chernobyl NPP:

- primary package - type KT-0.2a cask (200 dm3);
- shipping package - protective transfer cask, type KTZ-3.0;
- self-opening cask, 1.8 m^3;
- vehicle - special purpose vehicle.

8.7 Means to prevent fires and explosions, and store and transport materials, semi-finished products with hazardous and dangerous properties, performance of loading and unloading operations

No storage and transportation of materials and semi-finished products with dangerous and hazardous properties are performed within the CSFSF.

The following fire safety system are anticipated for the designed facility:

- external fire safety water pipeline with installation of fire plugs, designed in accordance with DBN V.2.5-74:2014 [20] requirements;
- internal fire safety water pipeline with installation of fire hose cabinets, designed in accordance with DBN V.2.5-64:2012 [46] requirements;
- fire alarm system, designed in accordance with requirements set in DBN V.2.5-56:2014 [21], DSTU-N CEN/TS 54-14:2009 [23];
- automatic gas and powder type fire suppression systems, designed in accordance with requirements set in DBN V.2.5-56:2014 [21], DSTU 4466-1:2008 [24], and DSTU 4466-8:2008 [25];
- public address and evacuation control system, designed in accordance with requirements set in DBN V.2.5-56:2014 [21], DSTU-N CEN/TS 54-14:2009 [23];
- alarm messaging system, designed in accordance with requirements set in DBN V.2.5-56:2014 [21];
- smoke control systems, designed in accordance with requirements set in DBN V.2.5-56:2014 [21];
- emergency lighting (escape, safety), designed in accordance with requirements set in DBN V.2.5-28-2006 [19];
- lightning protection, designed in accordance with requirements set in DSTU B V.2.5-38:2008 [26].

The design also provides for equipping the facility area, buildings and structures with primary fire extinguishing means (fire safety boards placed within the facility area and equipped with fire extinguishers, boxes with sand, fire blanket of nonflammable materials, pike poles, crowbars, buckets, as well as fire extinguishers placed inside the facility buildings and structures) in accordance with requirements set in the regulatory documents NAPB A.01.001-2014 [27] and NAPB B.03.001-2004 [28].

For the purpose of localization of the fire source, alarm about its outbreak, control of fire annunciators, signal lines and buses, receipt and processing of the data, formation and issue of signals about fire and failure, the design makes provision for the analog addressing automatic fire safety and control system certified in Ukraine.

Fire alarm and automatic fire suppression (AFSS) systems include

:

- fire alarm control unit (FACU) with address automatic and manual fire alarm boxes, controlled loop signal lines,

- control and protection modules, and programmable addressable control modules, installed - depending on the purpose - as close as possible to the protected object, which are responsible for execution of the algorithms of control and elaboration of control actions onto operating mechanisms, as well as data transmission to FACU.

Fire alarm system control units are also responsible for generation of the *Fire in CSFSF* signal and its feeding to the centralized surveillance post.

Fire safety of the cabling is ensured by means of the following actions:

- use of the cables of all purposes (power, control, automatics, communications etc.) with flame-retardant insulation;
- use of the power cables of the automatic fire alarm, suppression and public address systems with flame-retardant and fireproof insulation, with fire resistance of at least 30 mins IAW DBN V.2.5-56: 2014 [21];
- arrangement of passive fire proofing of the cabling.

Passive fire proofing includes application of fire protective compound onto cable routes (assurance of flame retardance), creation of flame arresting belts on cable routes, and fire protection padding (closing) of cable passages (localization of fire within one route or premise). Fire prevention measures to ensure fire proofing (cable coating, flame arresting belts, fire protection padding of cable passages) shall be taken in accordance with requirements set in the Fire Proofing Rules (Order of the Ministry of Emergencies of Ukraine no.460 of 02 July 2007) and regulatory documents establishing requirements to installation of engineering utilities: DBN V.1.1.7-2002 [17], VBN V.1.1-034-03.307-2003 [29] and NAPB B.01.014-2007 [30].

The provision is made of the use of fire protective materials Siloterm EP-6 by ELOKS.

The design provides for 10 kV cables and under 1 kV cables with class A flame-retardant insulation.

After the tender, the Customer may choose other manufacturers of cable products and fire protective materials on condition if they are manufactured under the similar specification requirements and if there are UkrSEPRO conformity certificates as for the products, upon which fire safety requirements are imposed.

Loading and unloading operations operations are performed by the personnel in accordance with requirements of NPAOP 0.00-1.01-07 [31], namely:

- at the work site and on the load lifting cranes and machines no persons having no direct relation to the performed work are allowed;
- in case of a need for inspection, repair, adjustment of mechanisms, electrical equipment, exit to the crane bridge deck, inspection and repair of hardware, crane operator shall switch the incoming switchgear off;
- cargo slinging is arranged by means of slings matching the weight of a lifted load, with consideration of the number of branches and their inclination to the vertical axis;
- general purpose slings are selected so as to ensure that inclination angle of the branches to the vertical axis does not exceed the permitted value;
- prior to transportation, the load is preliminary lifted to a height from 200 mm to 300 mm to check for proper slinging and reliable action of the brakes;
- during the lifting, relocation and lowering of the load placed near the wall, column, pile etc, no people (including the workers who attach the load) are allowed between the lifted load and the indicated parts of the building or equipment;

- load is lifted, relocated and lowered in case there are no people under it. Slingsman may stay near the load during the lifting or lowering operation if the load is at a height of not more than 1 m from the site on which the slingsman stands;
- the load is lowered down to a designated place where the load falling, tripping or sliding is excluded;
- loading and unloading operations, load relocation and piling with use of load lifting cranes and machines at permanent depots, sites, bases, in production and other premises, shall be be carried out under the process flowcharts developed and approved in accordance with the established procedure;
- load piping with use of load lifting cranes and machines is carried out at piping sites or in special places. This work may be performed only under the technology previously developed and approved by a company dealing with these operations, where order of operations, methods of load slinging, and measures on safe performance of works are determined.

In order to exclude electrocution of the personnel, the respective measures on the grounding of load lifting machinery are implemented in power supply systems in accordance with par.4.9 of NPAOP 0.00-1.01-07 [31], and on the use of appropriate PPE.

8.8 Actions to protect the workers from external and internal factors, availability of sanitary facilities and amenities, medical service

Most dangerous of the factors established by GOST 12.0.003-74* [32] for the CSFSF personnel are the following:

- electrocution;
- falling from height;
- increased noise level;
- increased temperature of the equipment surface;
- increased level of ionizing radiation in buildings and structures.

To protect the workers from negative impact of the above-listed external and internal factors, the following primary electrical means are provided for at Rivne NPP SUs, in accordance with par.5.2.7 of NPAOP 40.1-1.01-97 [34]:

- insulating rods;
- insulating tongs;
- personal shielding bundle, screens;
- tong-test instruments;
- voltage detectors;
- insulating gloves (up to 1000 V);
- tools with insulating coating (up to 1000 V).

Additional electrical means (determined in the job order as required):

- nonconducting footwear;
- dielectric mats;
- insulating pads and patches;
- voltage alarm devices;
- protective fencing;
- portable grounding, posters and safety signs.

Connection of the electric equipment shall be carried out by the personnel having at least IIIrd qualification group by electrical safety.

Protective means to prevent falling from height, in accordance with par 4.1.12 of NPAOP 00.0-1.15-07 [33]:

- safety belts;
- hardhats;
- lifelines;
- safety climbing gears;
- traps with vertical rope;
- fencing, safety meshes etc.

Personal protective equipment for protection from falling from height are ensured by a system of belts for their attachment to the worker's body and a system to fasten to a reliable support. Before performance of the high altitude works, it is necessary to ensure strengh of supports to which the worker(-s) will be fastened by the safety belt sling, as well as that of climbing gear elements. They have to reliably withstand force that may appear at falling of the people.

Means to protect workers from increased noise level (determined in the job order depending on the measured noise level):

- ear protection;
- ear plugs;
- antinoise ear plugs.

When in premises with the working power engineering equipment and in the repair area, all workers shall wear protective masks and hearing protection means.

For handling of decontamination solutions and dust control means, the personnel shall have a set of the following PPE:

- cotton fabric clothing;
- underwear;
- cap, socks, protective footwear;
- rubber gloves in bundle with cotton fabric gloves;
- appropriate personal respiratory protective equipment (PRPE) (to be indicated by the qualified specialist depending on a nature of a dangerous factor);
- flexible PVC apron and protective sleeves;
- flexible PVC overshoes or rubber boots;
- full-facial shield and glasses;
- hardhat;
- suit for protection from the used chemicals;

Type of the needed PPE is determined by the Safety Instruction specific for use of each individual chemical substance.

For protection from the impact of increased temperature, the personnel, when handling the HI-STAR and HI-STORM casks, shall use protective means determined in par.2.7 of DSN 3.3.6.042-99 [11], in particular:

- for continuous work - felted safety suit;
- for feet protection from heat radiation - special leather footwear;
- for hands protection - woolen, canvas gloves, combinated, with leather palm pads;

- for head protection - felted caps, protective hardhats with liners, textolite or polycarbonate helmets;
- for eyes and face protection - protective masks with transparent shield, heatproof shields.

Protective clothing shall have protective properties excluding heating of its inner surfaces at any area to the temperature of 40°C IAW GOST 12.4.176-89 [36], GOST 12.4.016-87 [37].

Primary and additional packages of PPE shall be used to ensure personnel safety against radiation impact. In accordance with par.12.5.4 of the Principal Sanitary Safety Rules of Ukraine [12], primary PPE package includes:

- overall or suit;
- cap;
- underwear and socks;
- footwear;
- gloves;
- respiratory protection equipment depending on possible radiation contamination of the air.

Additional PPE package includes:

- open or closed type glasses;
- arm and head pads, full-face shields;
- protective gloves, aprons, sleeves, shields for hands and body protection, protective footwear etc.

Additional PPE are selected at preparation of the joint job order and determined by the type of works and radiation conditions of these work performance sites.

Medical aid to the personnel has to be rendered at a first-aid station located in the administrative building.

For public catering a provision is made for a buffet designed for 50 visitors, in the administrative building, and in the guard building - mess room.

In the acceptance building, on the 1st floor it is anticipated to locate sanitary facilities and amenities (locker room, showers, wash hand basins etc.) and sanitary control post for operational and attracted personnel of the controlled access zone.

Structure of the sanitary facilities and amenities is determined depending on the number of the placed production personnel, its classification by appropriate groups of the production process, and their characteristics in accordance with requirements set in DBN V.2.2-28:2010 [35].

8.9 Information on benefits, permissibility of women's and teenagers' work

At the CSFSF it is provided for provision of benefits and compensations for work in hazardous working conditions as per the valid laws, in particular:

- right for preferential pension coverage per List 1 and 2 (decree no.10 of 26 January 1991);
- free healthful and dietary meals;
- reduced working day and working week;
- increased duration vacation;
- free personal protective equipment;
- sanitary and hygienic breaks.

Exact list of benefits will be established after the facility is commission and after attesting and hygienic classification of the labor by harmful exposure and danger of production environment factors at workplaces are performed in accordance with the Decree no.442 of the Cabinet of Ministers of Ukraine dated 01 August 1998 *On the Procedure of Workplace Evaluation with Respect to Working Conditions* and the Document *Hygienic Classification of Labor by Hazard and Danger of Production Environment Factors, and Working Process Difficulty and Intensity* [38] approved by the Order of the Ministry of Public Health of Ukraine no.248 of 08 April 2014.

Permissibility of women's labor - in accordance with the valid laws. Attaction of persons under 18 as well as handicapped persons to the work is not anticipated.

9. PERSONNEL NEEDS

In accordance with the Customer-provided data (letter from PC Atomproectenginiring, ref.no.03-46/260 of 17 February 2016), core activities at the CSFSF site will take place on a single-shift basis, five days a week, 220 days per year. The shift duration is eight hours.

Manpower of the personnel with indication of a group of production processes per DBN V.2.2-28:2010 [35] is provided in Table 9.1.

Table 9.1 **Manpower of the personnel with indication of a group of production processes**

Position	Number per staffing plan	Maximum shift	Group of production processes per DBN V.2.2-28:2010 [35] (Tab.4)	Location of sanitary facilities and amenities
ADMINISTRATION				
Director	1	1	1a	AAB
Principal Engineer	1	1	1a	AAB
Deputy Director for Physical Security (Service Chief)	1	1	1a	AAB
Deputy Principal Engineer - Chief Mechanic	1	1	1a	AAB
Chief Accountant	1	1	1a	AAB
Inspector for NRS, OS&H	1	1	1a	AAB
Inspector for Fire Safety	1	1	1a	AAB
Inspector for NM accounting and	1	1	1a	AAB
HR Inspector	1	1	1a	AAB
Total	**9**	**9**		
ADMINISTRATION GROUP				
Group Manager	1	1	1a	AAB
Engineer	2	1	1a	AAB
Documentation Clerk	2	1	1a	AAB
Counsel	2	1	1a	AAB
PR Manager	1	1	1a	AAB
Total by the Group	**8**	**5**		
FINANCE AND ECONOMY UNIT				
Head of the Unit	1	1	1a	AAB
Accountant	1	1	1a	AAB
Cost Controller	1	1	1a	AAB
Total by the Unit	***3***	***3***		
PRODUCTION AND TECHNICAL UNIT				
Head of the Unit	1	1	1a	AAB
Environment Protection	1	1	1a	AAB
Civil Engineer	1	1	1a	AAB

Position	Number per staffing plan	Maximum shift	Group of production processes per DBN V.2.2-28:2010 [35] (Tab.4)	Location of sanitary facilities and amenities
Human Resource Training Engineer	1	1	1a	AAB
Process Engineer	2	2	1a	AAB
Total by the Unit	**6**	**6**		
PHYSICAL SAFETY UNIT				
Head of the Unit	1	1	1a	AAB
Specialists, Engineers	17	6	1a	AAB, Guardhouse, Checkpoint 1
Total by the Unit	**18**	**7**		
THERMAL				
Head of the Shop	1	1	1a	AAB
<u>*TE Area*</u>				
Foreman	1	1	1a	Acceptance Building
Engineer	1	1	1a	Acceptance Building
Harness and Finished Products Warehouse Fitter	3*	1	1b	Acceptance Building, Train Crew
Crane Operator	2	2	2g	Acceptance Building
Slingsman	3*	1	2g	Acceptance Building, Train Crew
<u>*Welding Area*</u>				
Foreman	3*	1	1a	Acceptance Building, Train Crew
Engineer	1	1	1a	Acceptance Building
Fitter	3*	1	1b	Acceptance Building, Train Crew
Welder	3*	1	1b	Acceptance Building, Train Crew
Total by the Shop	**21**	**12**		
RADIATION SAFETY				
Head	1	1	1a	AAB
Dosimetrist	6	2	1c	Acceptance Building
Personal Dosimetry	2	1	1c	Acceptance Building
Total by the Shop	**9**	**4**		
AUXILIARY SYSTEMS SHOP				
Head	1	1	1a	AAB
Ventilation, Sewage and Heat Supply Area				
Foreman	1	1	1a	Acceptance Building
Engineer	1	1	1a	Acceptance Building
Maintenance Fitter	2	1	1b	Acceptance Building
Instrumentation Power Supply Area				
Foreman	1	1	1a	Acceptance Building

Position	Number per staffing plan	Maximum shift	Group of production processes per DBN V.2.2-28:2010 [35] (Tab.4)	Location of sanitary facilities and amenities
Engineer	1	1	1a	Acceptance Building
Electrical Fitter	1	1	2d	Acceptance Building
Communication Operator	1	1	1a	Acceptance Building
Programming Engineer	1	1	1a	Acceptance Building
Maintenance Electrician	6	2	1b	Acceptance Building
Instrumentation Technician	3	1	2d	Acceptance Building
DPP Operator	1	1	1a	Acceptance Building
Repair and Mechnical Works Area				
Foreman	1	1	1a	Acceptance Building
Engineer	1	1	1a	Acceptance Building
Fitter	7	7	1b	Acceptance Building
Machine Operator	1	1	1a	Acceptance Building
Technician	1	1	1b	Acceptance Building
Rail and Motor Transport Area				
Foreman	1	1	1a	Acceptance Building
Motor Vehicle Driver	4	3	1a	Acceptance Building
Cargo Carrier Operator	2	1	1a	Acceptance Building
Rairoad Engineer	2	1	1a	Acceptance Building
Rolling Stock Repair Fitter	4	2	1b	Acceptance Building
Technician	2	1	1a	Acceptance Building
Total by the Shop	**42**	**33**		
OPERATING PERSONNEL				
Shift Supervisor	6	1	1b	Acceptance Building
Engineer	6	1	1b	Acceptance Building
Lineman	20**	4	2d	Acceptance Building
Total operating personnel	**32**	**6**		
ADMINISTRATIVE AND MAINTENANCE UNIT				
Head of the Unit	1	1	1a	AAB
Production Area Cleaner	5	5	1a	AAB
Storekeeper	1	1	1a	AAB
Medical Nurse	2	1	1a	AAB
Total by the Unit	**9**	**8**		
LABORATORY				
Head	1	1	1a	Acceptance Building
Laboratory Assistant	2	1	1a	Acceptance Building
Total by the Laboratory	**3**	**2**		

Repl. Ref.no.

Signature, Date

Position	Number per staffing plan	Maximum shift	Group of production processes per DBN V.2.2-28:2010 [35] (Tab.4)	Location of sanitary facilities and amenities
TOTAL CSFSF	**161**	**95**		
* the number is determined by non-exceedance of the individual yearly radiation exposure dose and clarified under precommissioning works results ** the number is determined by non-exceedance of the individual yearly radiation personnel exposure dose with consideration of the designed capacity of the storage; number of the personnel increases incrementally with filling of the storage				

Personnel numbers indicated in the table is subject to confirmation and adjustment prior to putting the facility into operation.

In addition to the CSFSF personnel, in accordance with the National Guard of Ukraine, at the facility there may be up to 58 servicemen of the National Guard of Ukraine at the regular mode of service, and up to 68 servicemen in case of enhanced service mode. The National Guard personnel shall be deployed in the guardhouse and checkpoint 1 buildings.

10. NUCLEAR AND RADIATION SAFETY

CSFSF designing, construction and operation activity shall be carried out in accordance with the laws of Ukraine and other statutory acts regulating relations in the area of the use of nuclear energy, spent nuclear fuel and radioactive waste handling.

Requirements of the following documents were accounted at development of the CSFSF design:

- International Treaties, ratified in Ukraine;
- laws of Ukraine;
- Presidential decrees and Resolutions/Decrees of the Verkhovna Rada and the Cabinet of Ministers of Ukraine;
- regulatory documents of Ukraine on nuclear and radiation safety;
- hygienic normatives applied in the Chernobyl NPP exclusion zone.

ICRP and IAEA recommendations are used in that of their extent which do not contradict with the requirements of the above documents and are aimed at reduction of radiation impact on the personnel, population and natural environment.

10.1 Safety Assurance Principles

Main regulatory technical document that establishes principles and criteria of the CSFSF safety, classification of the CSFSF systems and elements, and requirements to assurance of the safety at all stages of the CSFSF life cycle (choice of the site, construction, commissioning, operation and decommissioning) is *The Main Provisions on Assurance of the Safety of Intermediate Storages for the Spent Dry Type Nuclear Fuel*. (NP 306.2.105-2004) [39].

Pursuant to NP 306.2.105-2004 [39], the CSFSF satisfies the safety requirements if at normal operation, operational occurrences and design basis accidents individual exposure doses do not exceed dose limits established by the valid norms in respect to the personnel and the dose limit quota for the population, and emissions and discharges of radioactive substances into the environment at all stages of the CSFSF life cycle don't exceed permissible levels established by the valid norms.

According to NP 306.2.105-2004 [39], the CSFSF safety is ensured by implementation of the principle of the defense-in-depth, which is based upon the use of the system of successive physical barriers on the route of proliferation of radioactive substances and ionizing radiation into production premises and environment, as well as of the system of technical and organizational measures to protect the barriers and preserve their efficiency in case of radiation accidents.

SNF storage system shall provide for at least 2 barriers on the route of proliferation of radioactive materials and 1 barrier on the route of proliferation of ionizing radiation [39] (permissible is to combine radiactive material localization barrier with biological protection, and in this case fuel matrix of the SNF may not be considered as a barrier for localization of radioactive materials).

For ensuring the CSFSF safety, the system of technical and organizational measures forms 4 tiers of the defense-in-depth.

Tier 1 - creation of conditions, which prevent operational occurrences:

- assessment and selection of the site suitable for CSFSF placement;
- development of the design on the basis of conservative approach;
- quality assurance for the CSFSF systems and elements, and the performed works;

- CSFSF operation in accordance with the requirements of the regulatory documents, technical specifications, and operation manuals;
- maintenance of safety-critical systems and elements in good working order;
- selection of the CSFSF personnel and assurance of its necessary qualification level for normal operations, operational occurrences, accidental situations, and accidents;
- buildup of the safety culture.

Tier 2 - prevention of design-basis accoidents, development of the design-basis accidents and their transformation into beyond design basis via:

- timely localization of deviations from the design-established limits and normal operation conditions, and elimination of these deviations;
- efficient management of the system of technical and organizational measures in order to eliminate causes, which led to operational occurrences;

Tier 3 - management of beyond design basis accidents via:

- prevention of the uncontrolled development of beyond design basis accidents and mitigation of their effects;
- protection of physical barriers against destruction and maintenance of their operability in case of beyond design basis accidents;
- recovery of the CSFSF into the controlled state at which permanent cooling of the SNF and retention of radioactive substances by protective barriers are ensured

Tier 4 - planning of the personnel and population protection measures and actions via:

- establishment of the protected zone and surveillance zone around the CSFSF;
- preparation and implementation, as required, of the actions plan for personnel and population protection in case of radiation accidents.

Requirements to radiation safety and radiation protection of the personnel and population during practical activity at the CSFSF and in case of critical events are built upon principles of justifiability, non-exceedance and optimization in accordance with NRBU-97 [101] and NRBU-97/D-2000 [102].

Technical and organizational solutions on ensuring the CSFSF safety at the designing, operation, retrofitting and upgrade of the systems and equipment shall be proved by past experience or tests, appropriate research, positive practice of operation of prototypes or pilot installations, and comply with the valid norms, rules and standards on nuclear and radiation safety.

At the CSFSF there shall be provided system for accounting and control of nuclear materials in accordance with the Treaty between Ukraine and IAEA on the Guarantees in relation with the Nuclear Non-Proliferation Treaty, Regulation on the State Nuclear Materials Accounting and Control System, and Rules of Accounting and Control of Nuclear Materials at the Facility.

The CSFSF shall have efficient physical protection system in accordance with requirements of the Law of Ukraine on Physical Protection of Nuclear Installations, Nuclear Materials, Radioactive Wastes, Other Sources of Ionizing Radiation and the Rules of Physical Protection of Nuclear Materials and Nuclear Installations.

At the CSFSF there shall be ensured collection, processing and storage in the electronic database of the information on conditions of the use of nuclear fuel in the reactor and storage of the SNF in the spent fuel pools, which is transmitted from the NPP, from which the SNF is transported to the CSFSF for the long-term storage.

Pursuant to NP 306.2.105-2004 [39], the CSFSF systems and elements are broken down to the following classes, depending on their impact on the safety:

- safety-critical systems and elements - systems and elements, which failure, with consideration of a single error/fault of the personnel, may lead to the accident;
- systems and elements not affecting the safety.

10.2 General Design Safety Criteria and Requirements

Pursuant to NP 306.2.105-2004 [39]:

- the CSFSF project shall utilize the defense-in-depth principle;
- during designing of the CSFSF it is necessary to provide for sanitary and hygienic and organizational and technical measures to ensure radiation protection of the personnel and population;
- during designing of the CSFSF values of the parameters and characteristics of the CSFSF systems and elements and their states for normal operations, operational occurrences, accidental situations, and accidents are established;
- compliance of the designed CSFSF with the requirements and norms of the nuclear and radiation safety for normal operation and accidents is justified in PSAR.
- the design provides for technical and organizational measures and actions aimed at prevention of the personnel faults and mitigation of their affects during operation and maintenance of the CSFSF systems and elements;
- when designing the CSFSF systems and elements it is necessary to prefer systems and elements which functioning is based on passive action principle;
- it is necessary to provide for in the CSFSF design technical and organizational measures and actions aimed at prevention of design basis accidents and mitigation of their effects, in particular - at non-exceedance of the permissible levels of the personnel and population radiation exposure and levels of discharges and emissions into the environment;
- it is necessary to provide for in the CSFSF design technical and organizational measures and actions aimed at safe transportation of the SNF within the CSFSF site;
- it is necessary to provide for in the CSFSF design measures and actions on decommissioning of the facility.

10.3 Design Basis

10.3.1 SNF Characteristics

Characteristics of the nuclear fuel, which after its use in active zones of VVER reactors and storage in the NPP spent fuel pools, is subject to long-term storage at the CSFSF are given in Tables 10.1 - 10.4.

VVER-1000 reactors of the Ukraine’s NPPs have used and provide for the use of fuel assemblies (FA) of the following modifications: FA-M и FAA (manufactured by TVEL OJSC), FA-W (LTA), FA-W and FA-WR (manufactured by Westinghouse). Main characteristics of these FAs and absorber rods of the control and protection system (CPSAR) are given in Tables 10.1 - 10.3.

Generation 1 and 2 fuel assemblies are used in the active zones of VVER-440 reactors of the Rivne NPP Units 1 and 2. Fuel assemblies

VVER-440 consist of assemblies of 2 types: FA and working cartridges (WC). Number of the control and protection system cartridges (CPSC) consisting of the FA and follower is 37 pcs. Adjusting rod (follower) is the absorbing part of the CPS cartridge. Adjusting rod (follower) is an assembly consisting of the head, casing, bottom nozzle, internal cylinder tube and hexagon-shaped inserts. Insert material is borated stainless steel. Material of all remaining parts of the follower is stainless steel. Their main characteristics are given in Table 10.4.

Table 10.1**- Main design parameters of VVER-1000 reactor FA subject to storage at the CSFSF [140, 145]**

Description	FAM	FAA	FA-W, FA-WR	FA-W (LTA)
Size of the turnkey FA, mm	234	234	234	234
Fuel elements qty, pcs	312	303/306/312	306	312 (48 pellet-integrated burnable absorbers (PIBA)*)
FAG qty, pcs	-	9/6/0	6	-
FA height, mm	4570	4570	4583	4583
FA element height, mm	3830; 3837	3837; 3842	3898,13	3898,13
Height of new fuel column in cold state, mm	3530	3530	3530 (central zone 3225.3 and 2 blankets 152.4 each	3530 (central zone 3225.3 and 2 blankets 152.4 each
FA weight, kg	670	710-714	755/760	743
Weight of UO_2in FA, kg	455,52±4.50	491,4±4.5 494,5±4.5	550,4±5	536±5
Mass content of uranium isotope mix in FA elements, %	87.9	87.9	87.9	87.9
Mass content of ^{235}U in uranium isotope mix in FA elements (fuel enrichment), %	1.6÷4.4	1.3-4.4	2.0 – 4.2 (central zone), 0.71 (blanket)	3.0 – 4.4 (central zone), 0.71 (blanket)
Mass content of gadolinium oxide in FAG, %	-	5	5	-
Mass content of ^{235}U in uranium isotope mix in FAG (fuel enrichment), %	-	2.4 – 3.6	2.0 – 3.6	3.65
Fuel density (UO_2), g/cm	10.4 – 10.7	10.4 – 10.7	10.96	10.96
Burnable absorber rod used	yes	-	-	-
Max. permissible average depth of fuel/FA element/FAG burning, MW*day/kgU	49/-/-	55/59.1/-	-/62/-	-/62/-
Average depth of unloaded fuel burning, MW*day/kgU	42 (44 after introduction of FAA)	51	Expected - 50	43.69
Pressure of FA element filler gas, at 20ºC, MPa	2	2	1.896	1.896 (0.689 – in FA elements with PIBA)

Description	FAM	FAA	FA-W, FA-WR	FA-W (LTA)
Spacing between FA elements, mm	12.75	12.75	12.75	12.75
Fuel element cladding diameter (inner/outer), mm	9.1/7.72	9.1/7.73	9.144/8.001	9.14/8.00
Filling gas	Helium	Helium	Helium	Helium
Fuel used in fuel elements	UO_2	UO_2	UO_2	UO_2
Fuel used in FAG	-	$UO_2+Gd_2O_3$	$UO_2+Gd_2O_3$	UO_2+ZrB_2
Fuel pellet diameter, mm	7.57	7.57	7.844	7.84
Diameter of the center hole in a FE/FAG fuel pellet, mm	2.35 and 1.5	1.5 and 1.4	-	-
Diameter of the guide channel (GC), outer/inner, mm	12.6/11	12.6/10.9	12.6/11.0	12.6/11.0
Diameter of the central core (CC), outer/inner, mm	11.2/10.6	13.0/11.0	12.6/11.0	12.6/11.0
Qty of the spacer grid (SG)	15	15	16	16
Material of FE/FAG cladding	Alloy E110	Alloy E110	Alloy ZIRLOTM	Alloy ZIRLOTM
Structural materials: - Head and bottom nozzle parts	Steel 08X18H10T 12X18H10T	Steel 08X18H10T	Steel CF3, 304, 304L	Steel 304
- Guide channels	Steel 08X18H10T 12X18H10T	Alloy E635	Alloy ZIRLOTM	Alloy ZIRLOTM
- Central core	Alloy Zr-1%Nb	Alloy E635	Alloy ZIRLOTM	Alloy ZIRLOTM
- Spacer grids (SG)	Steel 08X18H10T 12X18H10T	Alloy E110	(13 pcs. - Zr-1%Nb 3 pcs. – Alloy 718)	1 - Zr-1%Nb 14 – Alloy 718
- Framework angle elements	-	Alloy E635	-	-
- Tension clips	XH77TЮP	EK 173-ID, XH77TЮP	Alloy 718	Alloy 718
Permissible FE cladding temperature, ºC - at storage - at short-term transient modes (total of up to 8 hours)	 350 450	 350 450	At At burnup ≤45 GW*day/tU 400 570	At At burnup ≤45 GW*day/tU 400 570
Note: *Test FA-W (LTA) manufactured by Westinghouse consists of 312 fuel elements, of which 48 FEs are with PIBA, filled in as				

Description	FAM	FAA	FA-W, FA-WR	FA-W (LTA)
with standard fuel pellets and with pellets with absorber (ZrB_2). Fuel pellets with coating of such absorber are similar to pellets of enriching uranium dioxide with the exclusion that cylindrical surface of the pellets is additionally coated with a thin layer of zirconium boride (ZrB_2) with a thickness of less than 0.025 mm. Pellets with this coating are in the central part of the fuel pellet column. Total length of the active (fuel) part of the fuel element is 3550 mm. Fuel elements with PIBA contain in the central part the column of pellets with ZrB_2 coating and length of 2905 mm. Between the central column and blankets there are two columns of standard (uncoated) pellets with the length of 160.1 mm each				

Table 10.2 **- Main technical characteristics of VVER-1000 reactor burnable absorber rods [140, 145]**

Parameter or characteristic	Value
BAR qty, pcs	18
Absorbing material	Chromium diboride in aluminum matrix (CrB2+Al)
Density of the absorbing material by boron (nominal), g/cm	0.020 – 0.065
Height of the absorbing material column (nominal), mm	3550
Nominal weight, kg	21
BAR height, mm	4250
Cladding material	Zr-1%Nb
BAR outer diameter, mm	9.1

Table 10.3 - **Main technical characteristics of VVER-1000 reactor control and protection system absorber rods (CPSAR) [140, 145]**

Parameter or characteristic	Value
1 AE qty, pcs	18
2 Absorbing material	
2.1 Mark (AE upper part)	Boron carbide (B_4C)
2.1.1 Density, g/cm3, at least	1.7
2.1.2 Height of the boron carbide column in cold state, nominal, mm	3200
2.2 Mark (AE lower part)	Dysprosium titanate ($Dy_2O_3 \cdot TiO_2$)
2.2.1 Density, g/cm3, at least	4.9
2.2.2 Height of the dysprosium titanate column in cold state, nominal, mm	300
2.3 Total height of the absorbing material column in cold state, nominal, mm	3500
3 AE cladding material:	
- in CPSAR 0401.12.04.000 496.00.070	Steel 06X18H10T
- in CPSAR 0401.12.04.000-01;-03 496.00.070-01.02	Alloy 42XHM
4 Outer diameter of AE cladding, mm	8.2
5 Thickness of AE cladding, mm - of steel 06X18H10T	0.6

85

- of alloy 42XHM	0.5 or 0.55
6 Weight, kg:	
- CPSAR 0401.12.04.000;-03 496.00.070;-02	18.5 ± 0.5
- CPSAR 0401.12.04.000-01 496.00.070-01	18.5-1.1
7 Max. service life, eff.hours	
- CPSAR 0401.12.04.0001), 496.00.0701) in the	15150
- CPSAR 0401.12.04.000, 496.00.070 in the group	52750
- CPSAR 0401.12.04.000-1; -032), 496.00.070-01;-0 2)	75600
Notes: 1) Operation of CPSAR 0401.12.04.000, 496.00.070 in the NR group after their use in the AZ group and vice versa is not permitted. 2) Including, in the NR group - not more than 25,500 eff.hours. Regulation on relocation of CPSAR 0401.12.04.001-01; -03, 496.00.070-01; -02 from the NR group to AZ group and vice versa is determined by the Consumer. It is allowed to calculate operating time in the NR group by actual duration of CPSAR location below the upper terminal disconnect switch.	

Table 10.4- **Main technical characteristics of VVER-440 reactor FA subject to storage at the CSFSF [140, 145]**

Description	FA		2nd Gen FA	
	WC	FA	WC	FA
Size of the turnkey FA, mm	145	144	145	
FA qty in reactor, pcs.	276 (Rivne NPP-1) 312 (Rivne NPP-2)	37	276 (Rivne NPP-1) 312 (Rivne NPP-2)	37
FE qty in FA, pcs.	126	126	120	
Qty of FE with gadolinium	-		6	
FA height, mm	3217	3200	3217	3200
FE/FAG height, mm	2536 / -		2601.5 / 2540	
Height of new fuel column in cold state, mm	2420 / -	2320 / -	2480 / 2360	
FA weight, kg	215	220	219	220
Fuel type	UO2		UO2/UO2+5%Gd2O3	
Weight of UO2 in FA, kg	136.96	131.17	143.8	136.7
Mass content of uranium isotope mix in fuel, %	87.9		87.9	
Uranium (isotope mixture) weight	120.2±2.5	115.2±2.5	126.3±1.9	120.3±1.
Mass content of uranium-235 in the uranium isotope mix (enrichment), %	1.6 – 4.4		1.6 – 4.6	
Mass content of gadolinium oxide in fuel, %	-		3.35	
Mass content of uranium-235 in the uranium isotope mix in FE with gadolinium (enrichment), %	-		4	
Fuel density	10.4 – 10.7		10.4 – 10.7	
Cartridge-average designed burnout of fuel in max.burnt	53.5	42	58	57.5

Description	FA		2nd Gen FA	
	WC	FA	WC	FA
cartridge, MW*day/kgU				
Average depth of unloaded fuel burning, MW*day/kgU	39		No data	
Pressure of FE filling gas, MPa	0.5 – 0.7		0.5 – 0.7	
Spacing between FE in FA, mm	12.2 – 12.3		12.3	
Thickness of FA, WC case, mm	1.5	2.0	1.5	
Fuel element cladding diameter (inner/outer), mm	9.1 / 7.73		9.1 / 7.73	
Fuel pellet diameter, mm	7.54 - 7.57		7.57 – 7.60	
Diameter of the center hole in a fuel pellet, mm	1.4 and 1.5		1.2	
Qty of the spacer grids	10		12	
Central core	1		1	
Diameter of the central core (outer/inner), mm	10.3 / 8.8		10.3 / 8.8	
FE cladding material	Alloy E110 (Zr-1%Nb)		Alloy E110 (Zr-1%Nb)	
Structural materials: - Head and bottom nozzle parts - Central core (CC) - Spacer grids (SG) - Case	Stainless Steel 12X18H10T Alloy E110 Zirconium alloy H1 Alloy E125		Stainless Steel 12X18H10T 08X18H10T Alloy E110 Alloy E110 Alloy E125	
Permissible FE cladding temperature: - at storage - at short-term transient modes (up to 8 hrs in total), °C	350 450		350 450	

10.3.2 Design Features of the CSFSF

The CSFSF is intended for the long-term storage of the SNF from units Nos. 1 and 2 of Khmelnitskyi NPP, units Nos. 1 to 4 of Rivne NPP, and units Nos. 1 to 3 of Yuzhoukrayinska NPP.

The CSFSF operation period shall be 100 years

The capacity of the CSFSF is 16,529 SFA, including 12,010 SFA from VVER-1000 reactors and 4,519 SFA from VVER-440 reactors

The CSFSF is based on the technology by Holtec International (hereinafter — Holtec). Main elements of the technology:

- MPC — multi-purpose cask;
- HI-STAR 190 UA (hereinafter—HI-STAR)—transportation cask;
- HI-STORM 190 UA (hereinafter—HI-STORM)—storage cask;
- HI-TRAC 190 UA (hereinafter—HI-TRAC)—transfer cask;
- cask transfer facility (CTF);
- cask transfer device (CTD);
- vertical cask transporter (VCT);
- car transporter for the HI-STAR.

The project provides for the reception of HI-STARs with an MPCs, concrete-casting of the HI-STORMs' shells, transfer of the MPCs from the HI-STARs to HI-STORMs, and the storage of the HI-STORMs, filled with spent nuclear fuel on the territory of the CSFSF.

10.3.3 Criteria conditioned by the environment, natural phenomena and man-induced impacts

CSFSF is to be located on the site between the villages of Stara Krasnytsia, Buryakivka, Chystogalivka and Stechanka in Kyiv Region within the exclusion zone with radioactive contamination after the Chernobyl disaster

In accordance with NP 306.2.105-2004 [39] and PiN AE-5.6 [7], safety-critical CSFSF systems and elements shall be designed with consideration of potential accident events occurring under special external natural and man-induced impacts.

Loads and impacts on the buildings and structures referring to safety non-critical systems and elements (SNCS) are adopted by the loads regulated by the general construction norms and rules, and in the part of seismic impacts - by DBN V.1.1-12:2014 [167].

Table 10.5 displays classification of buildings and structures by their impact on the safety.

Table 10.5 - Classification of the buildings and structures

Loc. on the Master Plan	Description of the building/structure	Safety specification IAW NP 306.2.105-2004 [39]	Object category by liability for radiation and nuclear safety IAW PiN AE-5.6 [7]	Seismic stability IAW PNAE G-5-006-87 [124]
1	Acceptance Building	SCS	I	I
2	Cask storage area	SCS	I	I
3	Maintenance building with an MPC warehouse	SNCS	III	III
4	Office building (subject to civil protection)	SNCS	III	III
5	Electrical equipment building	SCS	III	I
6	Garage	SNCS	III	III
7	Filling station	SNCS	III	III
8.1	Fire water supply pump	SNCS	III	III

Loc. on the Master Plan	Description of the building/structure	Safety specification IAW NP 306.2.105-2004 [39]	Object category by liability for radiation and nuclear safety IAW PiN AE-5.6 [7]	Seismic stability IAW PNAE G-5-006-87 [124]
	water supply			
8.2	Fire water tanks	SNCS	III	III
9.1	Guardhouse (subject to civil protection)	SNCS	III	III
10.1	CHECKPOINT 1	SNCS	III	III
10.2	CHECKPOINT 2	SNCS	III	III
11.1	Accumulating tanks for the polluted storm water	SNCS	III	III
11.2	Accumulating tanks for the clean storm water	SNCS	III	III
11.3	Storm water treatment facilities	SNCS	III	III
12	Household wastewater pump station	SNCS	III	III
14	Telecommunication tower with a modular building	SNCS	III	III
15	Automated radiation monitoring system post	SNCS	III	III

External natural processes, phenomena and factors which impacts on the buildings and structures of the facility are the initial events for accident situations and their consequences are referred to special ones.

10.3.3.1 Special natural impacts

List of the special natural processes and their impacts with consideration of which safety critical structures are designed is determined pursuant to the regulatory requirements of NP 306.2.105-2004 [39] and PiN AE-5.6 [7]. Parameters of the special impacts, as well as their loads on the structures in accordance with which the safety critical systems and elements are designed, are determined under the regulatory requirements of DSTU-N B.V.1-1-27 [168], DBN V.1.2-2:2006 [166] and under PiN AE-5.6 [7] in a conservative manner, as well as in accordance with the engineering survey data.

Extreme wind

Pursuant to DBN V.1.2-2:2006 [166] and PiN AE-5.6 [7], extreme designed wind load is: $W_0 \times К_п = 0.45 \times 2.5 = 1.125$ kPa.

Extreme snowfall

Pursuant to DBN V.1.2-2:2006 [166] and PiN AE-5.6 [7], extreme designed snow load is: $S_0 \times К_п = 1.59 \times 2 = 3.18$ kPa.

Extreme Air Temperature

Pursuant to DSTU-N B V.1.1-27-2010 [168]

- absolute minimum of the air temperature is minus 40°C
- absolute maximum of the air temperature is 40°C

Tornadoes and tsunamis

Pursuant to the Main Regulatory Requirements and Design Characteristics of Tornadoes for the Chernobyl NPP Site [169], Class 3 tornado will be taken as a basis for the design criteria at the CSFSF construction site.

Design characteristics of tornadoes with the indicated reliability of 1x10$_6$ are specified in Table 10.6.

Table 10.6

Design characteristics of tornadoes	**Value for the tornado with reliability of $1 \cdot 10_{-6}$**
Design tornado probability class, k_p	3.0
Exceedance probability (event/year)	$1 \cdot 10_{-6}$
Maximum rotational speed of the funnel, V_p, m/s	81
Tornado progressive motion speed, U_p (m/s)	20.3
Pressure difference between the center and the periphery of the tornado funnel, ΔPp (hPa)	81
Length of the tornado path, L_p (km)	28.6
Width of the tornado path, W_p (km)	0.29

There is no such natural phenomenon as tsunami encountered at the site.

Maximum design earthquake (MDE)

Earthquake intensity for the CSFSF site is adopted in accordance with the Main Regulatory Requirements and Design Characteristics of Earthquakes for the Chernobyl NPP Site. Letter of the State Construction Committee of Ukraine no.3/19-19 of 08.07.05, Annex C [170].

Pursuant to DBN V.1.1-12:2014 [167], intensity of earthquakes in the Chernobyl NPP and CSFSF region is characterized by:

5 intensity (OSR-2004-A map, recurrence - every 500 yrs);

intensity 5 (OSR-2004-B map, recurrence - every 1000 yrs);

6 intensity (OSR-2004-C map, recurrence - every 5000 yrs).

Soil characteristic by seismic properties IAW DBN V.1.1-12:2014 [167]:

Chernobyl NPP and SFSF-2 sites - class III;

CSFSF site - class II.

Design characteristics of earthquakes for application in assessment of seismic resistance of the buildings and structures at the Chernobyl NPP site are given in [170]. Development [170] bases upon results of seismic microzoning (Order no.10 of 21 January 1998 by the State Committee of Ukraine for Construction and Architecture: On Approval of the Map of Seismic Microzoning of the Chernobyl Nuclear Power Plant Production Site) and is performed with consideration of requirements set in the regulatory documents SNiP II-7-81*, PN AE G-5-006-87, PiN AE-5.6, and IAEA recommendations (## NS-G-1.6 and SSG-9) on the need to account the value of peak acceleration of the accelerogram (PGA) of MDE earthquake not less than 0.1g. Data [170] for MDE are characterized by PGA=0.127g, which exceeds I=intensity 7. The document accounts for increase of the intensity in δI=1 for class III soils by seismic properties.

Increase of intensity for the CSFSF site for seismic class II soils is not required.

Therefore, application of the design characteristics of earthquakes mentioned in [170] for the CSFSF complies with requirements of the valid regulations of Ukraine and IAEA recommendations, and application of such characteristics for CSFSF is conservative.

Flooding and underflooding

There are no external natural phenomena such as floods and underflooding at the CSFSF construction site.

10.3.3.2 Special external man-induced events

List of external man-induced initial events is determined pursuant to the regulatory requirements set in NP 306.2.105-2004 [39] and based upon the conservative approach under PiN AE-5.6 [7].

Special man-induced events at the construction site are conditioned both by technological processes at the facility and by human activity at the site and outside the construction site on the neighboring objects.

Parameters of the special man-induced impacts are determined by the technological requirements, and conservatively - by requirements set in the regulatory documents PiN AE-5.6 [7] and the Recommendations on Assessment and Mitigation of Consequences of External Accidents Impacts on the Nuclear Power Plants [171], and by the original data obtained from Ukraine's state Authorities (Annexes A, B, Volume 4.2.1).

Design-basis accident

There are no external man-induced initial events for calculation of consequences of design basis accidents, which may occur during technological operations, on the site.

Air blast

The need for accounting the impact of explosions on the buildings and structure may appear if there are potential sources of explosion hazard on the construction site or around it. They are divided into:

- stationary (explosion hazardous productions, warehouses etc.);
- mobile (all types of transport).

On the CSFSF site.

Pursuant to the technological process, on the CSFSF site there are no objects that may be potential sources of explosion hazard.

Outside the CSFSF site.

In accordance with [171], preliminary criterion for selection of potential sources of explosion hazard is safety radius under table 3 [171]. Safety radius for the class of our objects is R_s = 0.39 km. At such distunce, potential excessive pressure in the airblast front does not exceed 10 kPa.

According to the initial data obtained from the State Agency of Ukraine for the Exclusion Zone Control with letter no.01-2429/1.4.2 of 04 Nov 2015 (Annex A, Volume 4.2.1):

- all stationary objects, which may be potential sources of explosion hazard, are located in the town of Chernobyl and in the town of Pripyat at the distance of about 10 km. This distance is by 2 magnitude orders larger than the safety radius, which makes up R_s = 0.39 km < 10 km. Due to this, load of the air blast from the stationary potential sources is low as compared with the loads in case of tornado, so it is not considered in the calculation justifications.

- mobile potential sources of explosion hazard, in particular roads, which may be used for transportation of explosion hazardous cargoes, are located at the distance of more than 10 km from the CSFSF site, and the roads located within the safety radius are not used for transportation of the explosion hazardous cargoes. So, the nearest road to Vektor complex, which is located at the distance of 0.27 m from the site, is used for RW transportation only.

Airplane fall

Pursuant to NP 306.2.105-2004 [39], it is necessary, for the CSFSF, to consider as the initial accident event - airplane fall on the facility.

In accordance with the data received from the State Enteprise for Servicing of the Air Traffic of Ukraine - letter no.5.18-844 of 21 September 2015 (Annex B, Volume 4.2.1):

- there are no airfields within the radius of 40 km from the CSFSF site;
- within the radius of 10 km from the CSFSF construction site there are sections of the air traffic routes of airplanes of various types (Table 10.7);
- average daily frequency of the flights is up to 12 airplanes per day;
- main characteristics of the aircrafts are given in Table 10.7.

Table 10.7

Aircraft type	Takeoff weight (max), t
Airbus A320	77
Boeing 767-300	159
Boeing 737-500	52
Boeing 737-300	56
Bombardier Dash 8 Q400	26
Bombardier Canadair Regional Jet 100	22
Bombardier Canadair Regional Jet 200	24
Bombardier Canadair Regional Jet 900	37
Bombardier Challenger 300	18
Bombardier Global Express	42
Embraer ERJ 145	21
Embraer ERJ 190	48

10.3.4 Design criteria of mechanical loads

10.3.4.1 Loads and impacts on building structures

Design criteria of mechanical loads and impacts of the building structures are determined:

- by the structural failure consequence class IAW DBN V.1.2-14-2009 [49];
- by the class of responsibility for nuclear and radiation safety IAW PiN AE-5.6 [7].

For buildings with the consequence class SS3 and class I responsibility under PiN AE-5.6 [7], limit values of the design criteria are given in Table 10.8.
For buildings with the consequence class SS3 and class II responsibility under PiN AE-5.6 [7], limit values of the design criteria are given in Table 10.9.

Table 10.8 - Limit values of the criteria for the Acceptance Building

Criterion	**Limit value**
Limitation of vertical motion of the foundation $S_{\max,U}$	100 mm IAW PiN AE-5,6 [7]
Limitation of the relative difference of vertical motion of the foundation $\left(\Delta S/L\right)_U$, where L = distance between two points of the motion difference ΔS	< 0.003
Restriction of vertical stress in the basis σ_z with the value of the design soil resistance R	DBN A.2.2-10-2009 [6]
Strength	DBN A.2.6-98:2009 [177]
Limitation of the crack opening width	W_{max} = 0.4 mm; W_{max} = 0.3 mm DBN V.2.6-98:2009 [177], DSTU B.V.2.6-156:2010 Tab. 5.1 [178]

Table 10.9 - Limit values of the criteria for the Cask Storage Area

Criterion	**Limit value**
Limitation of vertical motions of the foundation $S_{\max,U}$	150 mm IAW PiN AE-5,6 [7]
Limitation of the relative difference of vertical motions of the foundation $\left(\Delta S/L\right)_U$, L – distance between the foundations	< 0.003 (Annex I, DBN V.2.1-10-2009 [6])
Restriction of the design pressure σ_z, by the design soil resistance R	DBN V.2.1-10-2009 [6]
Foundation strength	DBN V.2.6-98:2009 [177]
Limitation of the crack opening width	W_{max} = 0.4 mm; W_{max} = 0.3 mm DBN V.2.6-98:2009 [177], DSTU B.V.2.6-156:2010 Tab. 5.1 [178]

In accordance with DBN V.1.2-14-2009 [49], the established and accident design situation shall be considered.

In the established design situation loads shall be determined in accordance with recommendations of DBN V.1.2-2:2006 [166]. The following loads are taken into account: weight of the structures, weight of the equipment; snow; wind; crane; climate temperature. In the established design situation accounted are loads with the characteristic duration of the implementation of the same order as the established service life of the facility - Tef=100 years. Limit states of group 1 and 2 are studied with consideration of the responsibility coefficient γ_n=1.25 for group I limit states and 1.05 - for group II states.

In the design accident events it is necessary to consider group 1 limit states with accounting of the loads with typically low probability and duration of the implementation but which are important from the standpoint of potential failure consequences, responsibility coefficient γ_n=1.05.

Joint action of the loads:

- main for checking the structures in the established situation;
- emergency for checking the structures in the design accident events.

For checking the group I ultimate states used are main combinations, which include permanent loads with limit values, limit design values of variable impacts.

For checking the group II ultimate states used are main combinations, which include permanent impacts with with operational values, operational design values of variable impacts.

The accident combination, in addition to permanent and variable impacts, may include only one accident (special) load.

For main combinations, which include permanent and at least 2 variable loads, variables are adopted with the combinations coefficient ψ=0.95 for long-term loads and ψ=0.90 for short-term loads.

For accident combinations, which include permanent and at least 2 variable loads, variables are adopted with the combinations coefficient ψ=0.95 for long-term loads and ψ=0.90 for short-term loads, and the accident load is adopted with the combination coefficient ψ=1.00.

At calculation of the distributed control system the existing logical links between individual loads are taken to account - mutual exclusion, associated and simultaneous loads. The load may also be characterized as the alternate load.

Permanent loads are considered in all combinations.

10.3.4.2 Cask strength criteria

During the analysis the following has been reviewed in [139] for the normal conditions of HI-STAR-190 operation:

- Loads during transportation and technological operations. For hoisting gear HI-STAR 190 cask has stress limits anticipated by NUREG-0612 [172] document, which requires that total stress in the lifting point shall be less than 1/10th of the material strength limit, provided that the lifted cargo is under additional dynamic load. These ultimate values are applicable to the lifting pins of the container and threaded joints in the covers. Intensity of the stresses of the cask bottom forging during HI-STAR 190 lifting operation was also taken into account. The loads on the bottom forging being reviewed represent own weight of this bottom forging, as well as weight of MPC canister, fuel basket and fuel. For assessment of eligibility 15% strengthening of the load and ultimate values of the stress intensity were utilized.

Loads during transportation under normal conditions. Loads during transportation under normal conditions, which serve as a basis for the strength analysis, are determined in [123, 172], and include:

- reduced external pressure 60 kPa;
- increased external pressure 150 kPa;
- free falling from height of 0.3 m onto a hard horizontal surface at most vulnerable positioning of the cask;

- standard vibration loads typical for transportation;
- standard operation conditions (pressure and temperature).

Loads referring to the accident conditions of HI-STAR 190 operation are determined in [123, 172]. Such conditions, which are considered in [139], are:

- Free fallng from height of 9 m (30 feet);
- Perforation. Performation is divided into 2 potential extreme scenarios, in particular:

  - lateral perforation: this event includes free falling (shock absorbers are neglected) from the height of 1 m onto a fixed vertically installed rod of soft steel with the diameter of 15 cm with the edge radius (upper edge) of 6 mm. It is anticipated that the rod is of such length that will lead to maximum damage to the cask. The cask is believed to be falling in a horizontal position, and the point of penetrating force is located in the middle of the cask length;

  - top perforation: this event is similar to the previous one, except for the point that penetrating force is supposedly acting on the center of the cask cover. Due to the vicinity of bolted joints this case is considered as the extreme for the butt end penetration.
- Fire at the temperature of 800ºC;
- Submersion at the height of the water head at least 15 m;
- Deep water submersion under 200-meter head.

HI-STORM 190 system is designed for on-site storage throughout the entire design service life. Respectively, the cask system is designed to withstand normal and accident conditions of storage, as well as environmental conditions.

During the analysis the following has been reviewed in [139] for the normal conditions of HI-STORM 190 operation:

- Dead weight of the structure. HI-STORM 190 shall withstand static loads conditioned by weights of all of its components.
- Loads caused by transportation and technological operations. HI-STORM 190 shall withstand loads appearing during the normal transportation and technological operations. Pursuant to standard [176], in order to include any dynamic effects for account of the lifting operations, loads shall be increased by 15%.
- Pressure. HI-STORM 190 cask is uncapable of preserving the internal pressure due to its open design and, respectively, pressure of the environment and hydrostatic pressure are the only pressures it may sustain. External design pressure at normal conditions is established for the standard ambient pressure minus 1 atmosphere.
- Temperature. Design temperatures of HI-STORM 190 components are given in Table 10.10.
- Snow loads. Design snow loads are given in Table 10.11.

During the analysis the following has been reviewed in [139] for the abnormal conditions of HI-STORM 190 operation:

- Tripping. Free standing HI-STORM 190 maintains kinematic stability at the design environmental phenomena (tornado, earthquake etc.).
- Fire.
- Tornado. HI-STORM 190 shall withstand pressure, wind loads and impact of the flying objects, which appeared as a result of tornado. Characteristics of the tornado and flying objects are given in tables 10.12 and 10.13.

- Flooding. HI-STORM 190 system shall withstand flooding-associated pressure and hydrostatic forces. In case of the flooding, loads on HI-STORM 190 system include buoyancy effects, static pressure loads, and dynamic pressure due to the water speed. It is anticipated that in case of flooding HI-STORM 190 system will submerge deeply under water. Maximum depth of water submersion and water flow rate are given in table 10.11.
- Earthquake.

During justification of preservation of integrity of the auxiliary equipment under normal operating conditions, the following types of loads were determined - dead weight, loads during transportation and technological operations, temperature:

- Dead weight. Auxiliary element shall withstand static load appearing in the assembled system.
- Loads during transportation and technological operations. Hoisting gear shall withstand loads, which appear during performance of transportation and technological operations in the normal mode. In this case loads are skewed upward by 15% in order to account for possible dynamic effects, which appear during cargo lifting operations.
- Temperature. Values of mechanical parameters, which are taken into consideration during analyzing the strength of auxiliary equipment, shall correspond to the maximum average temperature by thickness of the metal under normal operating conditions.

Table 10.10 - **Design temperatures of HI-STORM 190 components**

HI-STORM 190 components	Design ultimate values of long-term temperatures under normal conditions (lasting events), °C	Ultimate temperature values under accident conditions (short-term events), °C
Outer protective container concrete	149	343
Outer protective container cover	232	371
Remaining part of the steel structure of the outer protective container	177	371

Table 10.11 - **Design temperatures of HI-STORM 190 components**

Object	Conditions	Value
Snow load, kPa	Normal	4.8
Maximum water submersion depth at flooding, m	Accident	38.1
Water flow rate, m/s	Accident	4.572
External pressure on outer protective container, kPa	Accident	68.95 (pressure drop max for 1 s) 34.47 (pressure drop in a steady state)

Table 10.12 - **Characteristics of the tornado**

Conditio	Value
Horizontal wind speed, m/s	101
Tornado progression speed, m/s	20.3
Route length, km	28.6
Route width, km	0.29
Pressure difference, hPa	10411

Table 10.13 - **Flying objects tha appeared as a result of tornado**

Description of the flying object	Weight,	Speed, m/s
Vehicle	1800	203
Hard solid steel cylinder with 200mm diameter	125	203
Hard sphere with 25mm diameter	0.22	203

10.3.4.3 Protective barriers tightness criteria

Confinement, which prevents release of the radioactive content of the MPC, is its completely welded design. Localizing MPC casing has no bolted joints or mechanical sealings.

Localizing MPC casing consists of the following components:

- MPC shell (internal and external)
- MPC bottom (internal and external)
- MPC cover (internal and external)
- MPC drain and ventilation opening covers (internal)
- Appropriate welds

MPC is built tight [140] in accordance with the ANSI N14.5 [163] definition: “tightness is defined as the degree of package containment assured by a shell that practically rules out any substantial leakage of the radioactive material. The attainment of this degree of containment must be demonstrated by the leakage velocity that equals, or is less than, 1×10^{-7} cm^3/s, in terms of air, with a pressure of 1 atm within the shell and a pressure of 0.01 atm or lower outside the shell”. Thus, the design of the MPC makes sure that leakage velocity never exceeds 1×10^{-7} cm^3/s with the pressure differential of 100 atm between the inner space of the MPC and the environment. MPC compliance with the structural requirements was shown in the course of analytical studies described in the document [139].

MPC is the localizing vessel of the HI-STORM 190 system. MPC design provides for ensuring the confinement for all radionuclides under normal operating conditions, at operational occurrences, and under conditions of the accident. Three main components of the MPC casing are shell, internal bottom and cover. Welding of the shell and its welding to the bottom is carried out a the manufacturing plant. The remaining welded joints of the localizing casing are executed at the NPP power units.

MPC cover consists of two sections welded together (referred to as the upper and lower sections). Only the upper part of the cover is considered as the localizing casing. The cover is intentionally made thick-walled by adding the lower part of the cover in order to minimize radioactive irradiation of the workers during MPC closing operations.

10.3.5 Heat criteria

HI-STAR 190 and HI-STORM 190 are significantly different in respect to the geometry, structural materials, design loads and design criteria, as well as requirements of the regulatory documents applicable to them.

General requirement to HI-STAR 190 and HI-STORM 190 casks is the requirement not to exceed maximum permissible temperatures of FE casings at normal operating conditions, opperational occurrences and design basis accidents. The following design criteria are established:

- Maximum permissible FE cladding temperature for the normal operating conditions is:
  - for FAM and FAA - 350°C;
  - for FA-W, FA-W, FA-WR, FA-W(LTA) - 400°C;
- For short-term transient and accident modes (up to 8 hrs), maximum permissible FE cladding temperature is:
  - for FAM and FAA - 450°C;
  - for FA-W, FA-W, FA-WR, FA-W(LTA) - 570°C;

In this case, maximum design basis residual heat emission of the cask is:

- 38 kW for MPC-31;
- 33 kW for MPC-85;

Pursuant to the design, transport package HI-STAR 190 (consists of HI-STAR 190 cask, MPC-31 or MPC-85 multipurpose cask and shock absorbing devices) in type B (U) package under PBTRM-2006 [123]. The following design requirements are set for HI-STAR 190 in accordance with [123]:

- HI-STAR 190 shall be designed for the range of ambient temperatures from -40°C t0 +38°C (normal operating conditions), with consideration of exposure to sunlight;
- HI-STAR shall be designed for a fire with duration of 30 min at the flame temperature equal to 800°C (accident conditions);
- HI-STAR shall be designed in such a way that the temperature on accessible surfaces of the package at the ambient temperature of 38°C and with no exposure to sunlight is not exceeding 85°C;

Design thresholds of the temperatures and pressures for HI-STAR 190 in accordance with [137] are given in tables 10.14 – 10.16.

Table 10.14 - **Design thresholds of HI-STAR 190 elements temperatures**

Description of the element	**Material**	**Design temperature limit for normal operating conditions,** °C	**Design temperature limit for abnormal operating conditions, °C**
Fuel basket	Metamic-HT	400	50
Support structures and solid plates	Aluminum alloy	400	50 0
MPC shell	Stainless steel.	316	42
MPC cover	Stainless steel	316	42

Description of the element	**Material**	**Design temperature limit for normal operating conditions,** °C	**Design temperature limit for abnormal operating conditions, °C**
MPC bottom	Stainless steel	316	427
Internal MPC shell	Cryogenic steel	232	371
Flange, bottom forging	Cryogenic steel	232	371 (accidents affecting the strength properties) 788 (fire)
Cask cover	Cryogenic steel	232	371 (accidents affecting the strength properties) 788 (fire)
Steel of the remaining elements of the cask	Carbon steel	232	371 (accidents affecting the strength properties) 788 (fire)

Table 10.15 - **Design thresholds of HI-STAR 190 elements temperatures**

Element	Material	Temperature limit for normal operating conditions, °C	Temperature limit for abnormal operating conditions, °C
Cover sealings	Stainless steel / Elastic sealing	120	≤ 20 h: 170 ≤ 3 h: 210
Neutron protection	Holtite-B	204	Preservation of the integrity of the neutron protection material in the inflammation scenario is not considered. During the fire it is conservatively anticipated that there is no reduction of Holtite-B material heat conductivity coefficient, and after the fire it is conservatively anticipated to replace Holtite-B with air
Gamma	Lead	316 (600)	316
Shock absorbers	Crumple aluminum	127 (260)	Strength properties of the crumple material are not calculated at or after the accident associated with fire.

Table 10.16 - **Design thresholds of the pressure for HI-STAR 190**

Conditis	Threshold pressure values, kPa
Normal transportation conditions	690 for MPC 345 for
Hypothetic accidents	1379 for MPC 690 for

In accordance with the design for HI-STORM 190 storage system (consists of HI-STORM 190 cask and MPC-31 or MPC-85 multipurpose cask) the following design requirements are set:

- not to exceed maximum permissible temperatures of FE casings at normal operating conditions, opperational occurrences and design basis accidents;
- pressure in MPC shall not exceed 690 kPa for normal operating conditions (long-term storage) and 1379 kPa for short-term transient and accident conditions [137];

Design thresholds of the temperatures of HI-STORM 190, in accordance with [137], are given in Table 10.17.

Table 10.17 - **Design thresholds of HI-STORM 190 temperatures**

HI-STORM 190 element	**Temperature thresholds for long-term storage conditions, °C**	**Temperature thresholds for abnormal operating conditions, °C**
Storage container concrete	149, Concrete section average temperature value	343, Local concrete (bioprotection) temperature, except for fire
Upper and lower plates of the storage container cover	232	371
Remaining parts of the steel structure	177	371
MPC shell	316	427
MPC basket	400	500
MPC basket support structures	400	500
MPC cover	316	427
MPC lock ring	260	427
MPC bottom	316	427

10.3.6 Nuclear safety assurance criteria

Main requirements valid in Ukraine as to assurance of the nuclear safety at all stages of the CSFSF life cycle are set in the regulatory and technical documents [39, 69, 146, 147, 123, 134]:

- NP 306.2.105-2004. Principal Dry-type Spent Nuclear Fuel Interim Storage Facilities Safety Guidelines;
- PNAE H-14-029-91. Safety Rules for Nuclear Fuel Storage and Transfer at Nuclear Energy Sites;

- PBYa-06-08-77. Nuclear Safety Rules at Transportation of the Spent Nuclear Fuel;
- PBYa-06-00-88. Main Nuclear Safety Rules at Processing, Storage and Transportation of Nuclear Hazardous Fissionable Materials;
- NP 306.6.124-2006. Nuclear and Radiation Safety Rules at Transportation of Radioactive Materials (PBPRM-2006);
- RD 306.8.02/2.067-2003. Recommendations on Structure and Contents of Spent Nuclear Fuel Storage Facility Safety Analysis Reports.

Main requirements of the Ukrainian RD [39, 69, 146] on nuclear safety applicable to the CSFSF systems:

- at SNF storage subcriticality of the systems and elements which contain fissionable materials shall be mainly ensured by the geometry of SNF location;
- for the systems and elements which contain fissionable materials, effective coeffic of neutron breeding K_{eff} at normal operating conditions, operational occurrences and at design basis accidents shall not exceed 0.95 ($K_{eff} \leq 0{,}95$);
- if $K_{eff} \leq 0.95$ conditions cannot be fulfilled only due to the SNF location geometry, additional means and measures are provided for in the design to ensure subcriticality, in particular fixed neutron absorbers or fuel burnout accounting;
- when analyzing the nuclear safety it is necessary to neglect the presence of the absorbing elements in SFA or SFA case structures, if such are not fixed, their absorbing properties cannot be determined or if their efficiency deteriorates due to the initial events;
- analysis of the nuclear safety shall be carried out with the account for the factors at which the SNF storage and handling system has maximum K_{eff} at normal operating conditions, operational occurrences and design basis accidents;
- it is necessary to consider errors in the methods of calculation of K_{eff}, concentration and isotope composition of neutron absorbers, as well as tolerances for the manufacture;
- if there is nuclear fuel with different enrichment degrees, it is necessary to consider the fuel with maximum degree of enrichment;
- spent nuclear fuel shall be considered as new if K_{eff} at burning reduces, except for the cases when the burnout depth is used as a nuclear safety parameter and is controlled by means of special devices;
- when analyzing the subcriticality assurance, it is necessary to consider presence of the neutron reflector;
- subcriticality assurance analysis shall be performed for the maximum design capacity of the system;
- equipment for the spent nuclear fuel storage shall be designed in such a manner that effective coefficient of neutron breeding does not exceed 0.95 even if the storage is filled with water, and at such volume, distribution and density of the water as a result of the initial events, which lead to the maximum K_{eff};
- in case of the temperature change at normal operating conditions and at initial events of the accidents it is necessary to consider such SNF state, which leads to the maximum K_{eff}.

10.3.7 Radiation safety and protection criteria

Main requirements valid in Ukraine as to assurance of the nuclear safety at all stages of the VVER CSFSF life cycle are set in the regulatory and technical documents [39, 123, 110]:

- NP 306.2.105-2004. Principal Dry-type Spent Nuclear Fuel Interim Storage Facilities Safety Guidelines;
- DHN 6.6.1-6.5.001-98. Ukrainian Radiation Safety Standards. NRBU-97;
- DHN 6.6.1-6.5.001-98. Radiation Protection Against Potential Irradiation Sources. NRBU-97/D-2000;
- DSP 6.177-2005-09-02. State Sanitary Rules "Main Ukrainian Radiation Protection Sanitary Rules". OSPU;
- NP 306.6.124-2006. Nuclear and Radiation Safety Rules at Transportation of Radioactive Materials (PBPRM-2006);
- RD 306.8.02/2.067-2003. Recommendations on Structure and Contents of Spent Nuclear Fuel Storage Facility Safety Analysis Reports;
- Core Reference Levels, Release Levels, and Action Levels with Regard to Radioactive Contamination of the Exclusion Zone and the Compulsory Evacuation Zone. DAZV of Ukraine no.800/53-13.

Radiation safety (RS) and radiation protection with respect to practical activity, in conditions of the current and potential exposure to radiation, in accordance with requirements set in NRBU-97, NRBU-97/D-2000 and OSPU-2005 [101, 102, 110] are ensured with use of the following principles:

- justifiability principle, in accordance with which any practical activity that is accompanied by the people exposure shall not be carried out if it is not a major asset for the exposed individuals or the society in general if compared with the harm it causes;
- optimization principle, in accordance with which individual dose levels and/or number of radiation-exposed individuals with respect to each source of the radiation mush be as low as practically possible with consideration of economic and social factors.
- non-exceedance principle, in accordance with which levels of radiation exposure from all significant types of practical activity shall not exceed the established limits of the doses.

In accordance with NRBU-97 [101], the following categories of radiation-exposed individuals are established:

- category A (personnel) - persons who permanently or temporary work in direct vicinity of the ionizing radiation sources;
- category B (personnel) - persons who directly are not dealing with the ionizing radiation sources but in relation with their workplaces location in the premises and on production sites of the facilities with radiation and nuclear technologies may be exposed to additional radiation;
- category C - all population.

Values of effective and equivalent dose limits for category A and B personnel and values of permissible levels of yearly entry of significant radionuclides via respiratory organs, as well as permissible concentration of radionuclides in the working zone air for category A personnel, are regulated by NRBU-97.

Numerical values of dose limits are established at levels, which exclude the possibility of appearance of determinated radiation exposure factors and, at the same time, guarantee so low probability of appearance of stochastic effects of the exposure that it is acceptable both for individuals and for the society in general.

For category A and B persons, dose limits are established in terms of individual yearly effective dose, external and internal radiation exposure, and equivalent doses of external exposure (limit of the yearly effective dose and limits of the equivalent dose of external exposure). Limitation of radiation exposure for category C persons (population) is ensured by introduction of limits of yearly effective and equivalent doses in the critical group of category C persons. The latter means that values of the yearly radiation exposure of persons which are on the critical group shall not exceed the dose limit established for category C.

Dose limits are given in table 10.18.

Table 10.18– **Dose limits [101]**

Organs or tissues	**Categories of exposed persons**		
	A1), 2)	B1)	C1)
D_{LE} (effective dose limit), mSv/year	20 3)	2	1
Limits of the equivalent dose of external exposure:			
DL_{lens} (for crystalline lens), mSv/year	150	15	15
DL_{skin} (for skin), mSv/year	500	50	50
DL_{extrim} (for hands and feet), mSv/year	500	50	-

Note:
Distribution of the radiation exposure dose during the calendar year is not regulated;
For women of child-bearing age (until 45 years old) and for pregnant women there are restrictions in force in accordance with par.5.6 of NRBU;
On average for any 5 successive years but not over 50 mSv for an individual year (DL_{max})

Design total dose of the external and internal current exposure of the personnel shall not exceed the dose limit established for the personnel, and for the population - quota of the dose limit established for this company/facility [110].

Quota of the dose limit for the CSFSF, in accordance with [101], is 40 mcSv/year for account of emissions, 10 mcSv/year for account of the critical type of water use, and 80 mcSv/year - total quota for account of the air and water ways of the dose buildup.

Also, for category A personnel NRBU [101] establishes permissible levels of skin exposure to beta particles (permissible density of the flow and specific maximum equivalent dose), as well as permissible levels of radioactive contamination of the work surfaces, skin (during the work shift), special clothing and PPE by alpha- and beta-emitting nuclides.

Values of the reference risks of potential exposure not exceeding the admissibility level are established in [102] and are 2×10^{-4} year^{-1} for personnel and 5×10^{-5} year^{-1} for population. Value of 'neglectibly low' risk is 5×10^{-7} year^{-1}.

According to [101], personnel protection from the radiation exposure shall be designed with 2-time reserve for the design by yearly effective and equivalent doses of the current and potential exposure

Pursuant to requirements set in [110], the CSFSF design shall establish design reference levels of the personnel exposure. With that said, RL values shall not exceed 70% [110] of the values of permissible levels established in NRBU [101].

The CSFSF will be built within the Chernobyl NPP exclusion zone contaminated with radionuclides after the accident of 26 April 1986. In this area valid are reference levels [112], which shall be considered when planning the measures related with the CSFSF construction and operation.

According to the document [112], category A personnel is all persons permanently working within the exclusion zone, regardless of the nature of the performed works. Based on this, all personnel performing works on the CSFSF site refers to category A under NRBU-97 [101].

Category C is the population living outside the Chernobyl NPP exclusion zone and compulsory evacuation zone.

Considering the above and with consideration of requirements set in [110, 112], the design establishes the following design reference levels of the personnel exposure (effective dose):

- 11.0 mSv/year for account of external exposure;
- 3.0 mSv/year for account of internal exposure.

Additionally, for works performed at the construction stage, established is the design reference level of the single-time (shift) effective dose - 0.08 mSv/shift. According to the Customer's data, during the CSFSF construction works shift duration is 10 hours.

In addition of the above criteria, the document [123] establishes design criteria of biological protection assurance during SNF transportation for HI-STAR 190 transport and storage container, which is classified under PBPRM-2006 [123] norms as a type B(U) package. According to these requirements, dose rate for HI-STAR 190 shall not exceed:

- 2 mSv/hour at any point of the package surface at normal operating conditions;
- 0.1 mSv/hour at any point at the distance of 2 m from the package surface at normal operating conditions;
- at accident conditions radiation rate at the distance of 1 m from the package surface shall not exceed 10 mSv if there is maximum radioactive content.

10.3.8 Fire and explosion protection

According to GOST 12.1.004-91 [179], fire safety of the facility is ensured by fire prevention and fire protection systems, to include organizational and technical actions and measures. Fire safety systems shall exclude fire breakout and ensure fire safety of the people.

Fire prevention is ensured by prevention of formation of combustible medium and/or prevention of formation of (or introduction) ignition sources in the combustible medium.

Prevention of the combustible medium formation is achieved through:

- maximum possible use of non-combustible and fire resistant substances and materials;
- maximum possible limitation of the weight and/or volume of combustible substances and materials and maximum safe method of their positioning;
- isolation of the combustible medium, maintenance of the safe concentration, temperature and pressure of the combustible medium, at which flame propagation is excluded;

- maximum automation of the technological processes associated with combustible substances handling;
- installation of fire-safe equipment in isolated premises and at open areas;
- use of protective devices to safeguard the production equipment with combustible substances from damages and accidents, installation of tripping/disconnecting devices.

Prevention of formation of ignition sources in the combustible medium is achieved by application of one of the following methods or their combination:

- use of machinery, mechanisms, equipment and devices which operation does not causes formation of the ignition sources;
- use of electric equipment in accordance with its fire hazard and explosion hazard rating
- use fast-action protective tripping devices for potential ignition sources in the design;
- use of the technological process and equipment satisfying the requirements on electrostatic intrinsic spark safety;
- arrangement of lightning protection for buildings, structures, and equipment;
- maintenance of the temperature of heating of the surfaces of machinery, mechanisms, equipment, devices, substances, and materials which may come in contact with the combustible medium at a leve lower than maximum permissible which is 80% of the lowest temperature of the fuel self-ignition;
- elimination of conditions for thermal and chemical self-combustion of the circulating substances and materials;
- use of non-sparking tools when working with easily combustible liquids and combustible gases;
- reduction of the determining size of the combustible medium below the maximum permissible value in terms of combustibility;
- observance of the valid building norms, rules, and standards.

Limitation of the weight/volume of combustible substances and materials, as well as the safest method of their placement is achieved by application of one of the following methods or their combination:

- reduction of the weight/volume of combustible substances and materials which are simultaneously kept in premises and at open sites;
- arrangement of the emergency drainage system for fire hazardous fluids from the machinery;
- periodic cleaning of the site, premises, utilities, equipment from combustible wastes, deposits, dust etc.;
- removal of fire hazardous wastes generated during operation of the facility;
- maximum possible replacement of easily combustible and combustible liquids with non-combustible ones.

Fire protection is achieved by application of one of the following methods or their combination:

- use of fire suppression means and appropriate types of fire protection machinery;
- use of fire alarm and automatic fire suppression (AFSS) system;
- use of main building structures and materials, to include those used for cladding of the structures, wit the rated values of fire hazard;
- application of fire protection paints (compounds) on the surfaces of building structures;
- appliances which ensure limitation of the fire development;
- organization, with use of technical means including automatic ones, of the timely warning and evacuation of people;

- use of collective and personal protective means to safeguard people from dangerous fire factors;
- use of smoke protection means.

Limitation of the fire development is achieved by application of one of the following methods or their combination:

- arrangement of fire protection barriers;
- establishment of standard-permitted areas for fire safety compartments (sections), number of floors in the buildings and structures;
- arrangement of emergency tripping and switching of installations and utilities;
- use of the means preventing or restricting spoilage and spreading of combustible fluids at fire;
- use of fire-stop assemblies on the equipment. Organizational and technical measures include:
- organization of fire guard;
- organization of the workers' training on the fire safety rules,
- development and implementation of fire safety rules and norms, manuals on handling of fire hazardous substances and materials, on observance of fire safety regime and actions of people in case of a fire;
- manufacture and use of visual aids on assurance of the fire safety;
- norming of the number of people at the site in accordance with their safety conditions in case of fire;
- development of measures on the management and personnel actions in case of a fire and organization of evacuation of people;
- equippage of the facility with fire fighting machiner that ensures efficient fire (inflammation) fighting.

According to par.2.15 of DBN V.1.1-7-2002 [17], buildings and premises of the production and storage purpose are classified in accordance with their explosion and fire hazard rating.

Determination of the categories of buildings, premises, structures and outdoor installations is performed on the basis of methods and requirements laid down in NAPB B.03.002-2007 [14].

10.3.9 Control criteria

The design provides for the CSFSF control and management system (CMS) that ensures comprehensive control and management of the technological processes on receipt and storage of casks with the spent nuclear fuel, as well as control and management of auxiliary systems.

CMS integrates separate primary systems into a single system thus allowing to perform comprehensive processing, display and storage of information in a single place - at the central control and monitor panel (CCMP).

CMS ensures maintenance of radiation and general technical safety at receipt of SFA and their storage. CMS executes the function of the information support for the personnel in a form convenient for perception and analysis in order to determine negative trends in a change of the state of hazard sources at the CSFSF and arrange measures to prevent development of these trends.

The following design criteria were used as the basis for the control and management system:

- reliability (to be achieved through the use of high-reliability components and optimal system structure, and hardware-based fault detection capabilities);

- openness of the system (to be achieved by means of additional components and subsystems as well as by means of integration with other information systems).

The design shall set up control over the safety barriers in case of long term SNF storage at the CSFSF. One of the control types shall provide for control over heat removal process. Heat removal process control during the SNF storage in HI-STORM is ensured by the system for remote control of the cask storage process, which structurally is a part of the CMS.

10.3.10 Criteria of the SNF extraction from the CSFSF

Criteria of the SNF extraction from the CSFSF:

- Normal operation - after expiry of the design period of the SNF storage at the CSFSF, i.e. in 100 years;
- Abnormal conditions - failure of the safety barriers during the storage. According to the results of the storage process control in case safe operation limits are exceeded.

The SFA management technology in the CSFSF is not anticipated. At normal operation, accident events and accidents anticipated is handling of the MPC that contains SFA.

10.3.11 Criteria or Guarantees and Physical Protection Assurance

The nuclear materials (NM) are subject to national and international control (IAEA) and inspections.

The CSFSF shall have a system to control and account nuclear materials in accordance with NP 306.7.122-2006 [180].

Nuclear Material Recordkeeping and Control Rules:

- nuclear materials shall be subject to the state recordkeeping and control starting from their minimum quantity established by the Rules [180];
- nuclear materials shall be classified according to their categories in order to ensure differential approach to determination of the recordkeeping and control procedures and methods;
- licensee shall coordinate with the SNRIU material balance areas (MBA) within the nuclear plant or nuclear material storage site;
- in each MBA determined should be reference measurement points (RMP) for nuclear materials;
- nuclear materials are covered by construction and design documents which confirms reliability of previous measurements of quantitative properties and attributes of the nuclear materials;
- recordkeeping of the nuclear materials shall base upon the results of measurements of nuclear materials quantitative properties.

Nuclear materials recordkeeping and control criteria at the CSFSF are assurance of the ongoing control of the available quantity of nuclear materials, facilitation in localization of potential losses, prevention of unauthorized use or theft of these materials.

Main principle for the recordkeeping and control is timely recording of every relocation of a nuclear material and every change in the NM inventoried quantity.

Unit of measurement for the recordkeeping purposes is a batch of fissionable nuclear material.

In the CSFSF recordkeeping system, unit of measurement of NM is a batch of nuclear material contained in one MPC.

In accordance with the Law of Ukraine on Physical Protection of Nuclear Materials, Nuclear Installations, Radioactive Wastes, and Other Sources of Ionizing Radiation (hereinafter - Law on Physical Protection) [181] and the Law of Ukraine no.638-15 on Anti-Terrorism [182], CSFSF physical security system (PSS) is created at the CSFSF.

The following principles were accounted during the PSS design process:

- physical security actions shall not impede observance of the process regulations of the CSFSF;
- physical security actions shall not deteriorate nuclear, radiation, fire and other types of the CSFSF security.

PSS is designed for detection of attempts and prevention of unauthorized entry to the CSFSF site, which may lead to willful actions aimed at incapacitation of the PSS engineering and technical means and, especially, critical CSFSF technical elements, as well as prevention of unauthorized relocation outside the facility of any radioactive substances and nuclear materials, to include prevention of sabotage acts, in accordance with the IAEA requirements INFCIRC/225/Rev.5 [183] and INFCIRC/274/Rev.4 [184], to include Convention of Physical Security of Nuclear Materials and Nuclear Plants, as amended in accordance with the Law of Ukraine no.356-VI of 03.09.2008 [185].

10.4 Nuclear Safety

10.4.1 Technical solutions on assurance of the nuclear safety

Nuclear and radiation safety during transportation and technological operations on the SNF is ensured by the structural solutions of the equipment and presence on the site of the system for monitoring of the state of HI-STORM with MPC.

Detailed description of the SNF handing operations is given in Part 1, Volume 3 of this design.

To confirm fulfillment of the requirements of Ukraine's regulatory documents (RD) with respect to nuclear safety assurance, Holtec International has performed necessary calculations [134-142].

Detailed justification of nuclear safety at normal operating conditions, opperational occurrences and accidents is given in the PSAR.

According to requirements of the regulatory documents [36, 69, 146], nuclear safety of the CSFSF is ensured by:

- limitation of the spacing between FAs in the MPC;
- limitation of the weight of fissionable materials in one MPC;
- use of heterogenic absorbers of thermal neutrons (installation and attachment of Metamic-HT neutron absorber in the MPC);
- control of technological parameters of the complex of nuclear fuel storage and handling systems.

Technical solutions associated with the design and materials of the MPC, HI-STAR and HI-STORM

SNF handling technology presented by Holtec anticipates that SNF is directly kept in multipurpose casks (MPC). MPC is double-walled tight welded cases made of stainless steel and filled with helium.

MPC is built tight [140] in accordance with the ANSI N14.5 [163] definition: “tightness is defined as the degree of package containment assured by a shell that practically rules out any substantial leakage of the radioactive material. The attainment of this degree of containment must be demonstrated by the leakage velocity that equals, or is less than, 1×10^{-7} cm^3/s, in terms of air, with a pressure of 1 atm within the shell and a pressure of 0.01 atm or lower outside the shell”. Thus, the design of the MPC makes sure that leakage velocity never exceeds 1×10^{-7} cm^3/s with the pressure differential of 100 atm between the inner space of the MPC and the environment. MPC compliance with the structural requirements was shown in the course of analytical studies described in the document [139].

Inside the MPC there is a basket for installation of FA, made of aluminum and structural material which is a neutron absorber (Metamic material).

Metamic is a compound metal matrix made of 99.5% pure aluminum reinforced with boron carbide. Minimum content of B_4C in the material is 9%. Burnout of neutron absorber ^{10}B during 100-year storage is neglectibly low and Metamic preserves its properties during the design CSFSF operation period, what is justified in the documents [137, 140].

MPC basket materials are aluminum and Metamic and ensure the required heat removal from the SNF. Presence of the inert atmosphere in the MPC (helium filling) ensures protection against corrosion of FE cases, what preserves their integrity during long-term storage. Inert atmosphere inside the MPC is maintained due to the reliability of tight and sealed MPC barriers. Tightness of the MPC within the design service life, at all design modes, is justified in the document [140].

HI-STAR and HI-STORM casks execute the function of MPC protection against external impacts [139, 143] and also radiation protection function [141, 143]. HI-STAR cask is made primarily of steel and Holtite material which contains 2% B_4C and serves, among other, as a neutron absorber. HI-STORM cask is made primarily of steel and concrete. Design and materials of HI-STAR and HI-STORM casks ensure MPC protection against external impacts [139, 143] and sufficient conditions of the SNF cooling in the MPC [138] at normal operating conditions, operational occurrences and at design basis accidents.

Technical solutions in the CSFSF acceptance building

In the acceptance building, technical solutions associated with assurance of the nuclear safety are aimed at reduction of the probability of mechanical damage to the MPC and exclusion of water access to SFA in case of accident MPC containment failure. It is related with the point that nuclear safety is primarily ensured by the MPC design.

To reduce the probability of mechanical damage to the MPC, it is anticipated to use in the acceptance building equipment of the seismic resistant design with enhanced reliability rating. Moreover, the design solutions ensures that handling with the MPC will occur only within the cask transfer facility (CTF) with use of the cask transfer equipment (CTE) what excludes MPC falling with destruction of barriers. The design also provides for ensuring the integrity and stability of the acceptance building as the object/facility referring to class I of responsibility for nuclear and radiation safety IAW PiN AE-5.6 [7].

For excluding the possibility of SFA contact with water in case of a hypothetic event with malfunction of the tightness barriers, there are no water supply in the acceptance building and the CTF.

No water is used in these premises when the fire safety systems are designed.

Throughout the entire process chain in the acceptance building ensures are at least 2 engineering barriers which prevent from water penetration to the SFA - tight casing of the MPC, cask casing or HI-STAR or HI-STORM.

Ensured is remote surveillance of all process operations and control of neutron radiation in that part of the acceptance building where MPC acceptance and transfer operations are performed.

HI-STAR used in the CSFSF is designed for falling from 9-m height without damaging its content. Maximum height of HI-STAR cask lifting in the acceptance building is 7 m.

Detailed description of the SNF handing operations and equipment in the acceptance building is given in Volume 3.1 of this design.

10.4.1.3 Technical solutions during on-site transportations

On-site transportation of HI-STORM which contains MPC with SFA inside is carried out by the on-site wheeled vehicles (OWV). Main element that ensures nuclear safety at transportation of SNF by the transporter is HI-STORM. Main technical solutions on assurance of the nuclear safety at on-site transportation are aimed at ensuring the protection of HI-STORM from mechanical damages during transportation.

The following technical solutions are implemented to ensure nuclear safety during on-site transportation of the spent nuclear fuel:

- transporter carries only one HI-STORM container with MPC during one trip, i.e. quantity of the transported nuclear material is limited by the design of the used equipment;
- transporter design and transporter route has no provisions for the use of water, what excludes hypothetic possibility of water contact with SFA;
- transporter design ensures lifting of the cask at the height of not more than 28 cm, what excludes damaging of HI-STORM in case of falling down during the transportation (HI-STORM is designed for falling from the height of 30 cm without any damage to the container and the contents);
- master plan of the site is developed in such a manner as to reduce the route of the transporter travel with HI-STORM from the acceptance building to the storage area and exclude crossing of the routes of the loaded transporter and other cargo transporters within the CSFSF site, what reduces the probability of accidents during transportation;
- transporter design excludes high-speed motion what excludes possiible personnel’s faults in relation to the transporter traffic regulations and, respectively, reduces the probability of the container falling during transportation.

Detailed description of the equipment and technological process of the SNF transportation to the storage area is given in Volume 3.1 of this design.

10.4.1.4 Engineering solutions at the storage area in the CSFSF

The following technical solutions are implemented to ensure nuclear safety during the storage of the spent nuclear fuel:

- for MPC storage used in HI-STORM Protective container which design is rated for extreme impacts up to the aircraft fall. Even in this case the container and, respectively, MPC remain undamaged;
- to exclude flooding of the storage area the provision is made for the storm water drainage system intended for removal of water from the maximum daily precipitation rate in the CSFSF area;
- permanent uninterrupted control of the temperature at the entry and exit of HI-STORM ventilation channels, which reflect the state of the MPC heat release and, respectively, state of the MPC;
- selected area for construction of the CSFSF has low level and amplitude of groundwater level fluctuations what excludes initial accident event with flooding of the site and, respectively, water penetration to the MPC via HI-STORM ventilation channels;
- selected area for construction of the CSFSF is located far from water basins and rivers what excludes initial accident event with flooding of the site and, respectively, water penetration to the MPC via HI-STORM ventilation channels;
- the storage area is located inside of the secured CSFSF perimeter and is separated into an extremely important zone which prevents access of unauthorized personnel;
- the provision is made for the scheduled patroling of the storage area by the CSFSF personnel for detecting any possible clogging of HI-STORM ventilation channels and their timely cleaning;
- materials used during designing of the storage area are such non-combustible materials which exclude such initial event as fire.

Detailed description of the HI-STORM container servicing operations in the storage area is given in this design, Volume 3.1 “Technological Part. Part 1. Spent Fuel Handling Description of the CSFSF Master Plan is given in Volume 2. Detailed description of the control and management system (control of the temperature at the entry and exit of HI-STORM ventilation channels) is given in Volume 6 of the design.

10.4.2 Subcriticality assessment

Holtec International has performed calculations [136] which assess subcriticality of HI-STORM 190 and HI-STAR 190 systems for the spent nuclear fuel storage and transportation for the CSFSF (the copy is attached in Volume 1.2.2). These calculations confirms non-exceedance of the maximum value of the effective coefficient of neutron breeding $_{eff}$ 0.95 for HI-STAR 190 casks and HI-STORM 190 storage module with MPC-31 and MPC-85 for transportation and storage of the undamaged VVER-1000 and VVER-440 spent nuclear fuel at normal operating conditions, operational occurrences and at design basis accidents.

The document [136] provides assessment of subcriticality of the spent nuclear fuel in the following types of the casks:

- HI-STAR 190 - transport cask, type B(U)F, made of steel, lead and Holtite material;
- HI-STORM 190 - storage cask, made of steel and concrete;

- HI-TRAC 190 - transfer cask, made of steel and lead, also contains water in the water jacket.

The above casks may be loaded with the following modifications of the multipurpose cask (MPC):

- MPC-31 with 31 storage cells built with consideration for VVER-1000 undamaged spent fuel (fuel material - UO2) with the rated maximum enrichment for $_{235}$U;
- MPC-85 with 85 storage cells built with consideration for VVER-440 undamaged spent fuel (fuel material - UO2) with the rated maximum enrichment for $_{235}$U;

Assessment of subcriticality of the casks in the paper [136] was performed with use of MCNP5 computer code - 3D-code of general purpose based on Monte-Carlo method developed by Los Alamos National Laboratory in the USA.

10.4.2.1 Methods

HI-STAR 190 - hereinafter HI-STAR - is the main element of the transport package designed for transportation of multipurpose casks loaded with VVER-1000 and VVER-440 SNF. HI-STORM 190 - hereinafter HI-STORM - is a thick-walled cask, partially made of concrete, for long-term storage of the SNF at the CSFSF. HI-TRAC 190 - hereinafter HI-TRAC - is a transfer cask used for loading of SNF into MPC (MPC is filled with water inside HI-TRAC) as well as for transferring the dry MPC into HI-STAR. MPC fuel basket is built in such a way that fixed neutron absorber in its structure preserves its efficiency during the storage over 100 years, and it should be mentioned that there are no reliable mechanisms which could reduce or deteriorate its efficiency. Respectively, there is no need for actions to monitor and control long term efficiency of the neutron absorber. Three used casks (HI-STAR, HI-STORM, and HI-TRAC) differ only by the external reflector material, what insignificantly affects the breeding properties. Respectively, analysis results for the cask of one type are applicable to other types as well. Therefore, most calculations for justification of the nuclear safety during transportation and storage of the spent nuclear fuel were carried out only for one of three containers, namely for HI-STAR. Nevertheless, calculations for assessment of the nuclear safety was also performed for HI-TRAC and HI-STORM what is mentioned in Chapter 7.4.

HI-STAR localization system is represented by 2-walled multipurpose cask (MPC) with flat bottoms and flat welded covers (internal barrier) and metal package cask with bolted cover (external barrier). Therefore, multibarrier tight localization system is ensured, in which the metal package cask with bolted cover ensures only the external barrier. Inside the MPC the SFA are located in the basket cells which ensure their permanent position. At normal and accident conditions of transportation HI-STAR transport cask is in dry state (without moderator) due to which breeding capability of the system is very low (Keff < 0.50).

Nuclear safety during transportation and storage depends on the following main design parameters:

1. Geometry of the fuel baske inside MPC;

2. Permanent fixed neutron absorber in the composition of the fuel basket. The basket is completely made of Metamic-HT - composite material consisting of

aluminum and B_4C. Therefore, all SFAs are completely surrounded by neutron absorbing material;

3. Specified limit for the maximum fuel enrichment;
4. Capability of the system to prevent water penetration at accident conditions.

Due to this capability of the system any possible modification of the fuel configuration at accident conditions will have no consequences from the standpoint of nuclear safety.

For identification of the degree of the impact of tolerances and deviations during manufacture of the fuel and MPC basket on K_{eff} of the system, sensitivity analysis was carried out in the paper [136]. For calculations used was the worst combination of tolerances and alignments, i.e. such combination that leads to increase of the system's breeding properties.

Assessment of subcriticality of the casks in the paper [136] was performed with the following conservative assumptions, which comply with the criteria [39]:

- considered were systems with maximum design capacity of SFA loading;
- MPC basket is completely loaded with the fuel with maximum breeding properties;
- formed was the combination of the worst conditions from the point of tolerances and alignments;
- performed were analysis for cases of absence and presence of the water as the moderator and external reflector. Varied were water density inside the cask, water level inside the cask at vertical and horizontal flooding, water density outside the cask, presence or absence of the neighbor casks, as well as distance to the neighbor casks. As a result, the conditions, which lead to maximum breeding properties of the system, were taken as the final ones;
- analysis was performed for loading of the new fuel with maximum enrichment;
- in the new fuel presence of ^{234}U and ^{236}U, which are additional neutron absorbers, was not considered;
- presence of the burnable absorbers was not considered;
- calculations of the flooding with the moderation used water which temperature matches the maximum breeding capability of the system;
- absorbing properties of the FA structural elements were neglected;
- during creation of the design diagram of HI-STAR casks and HI-STORM storage module materials absorbing the neutrons, such as Holtite and steel beyond Holtite, were not considered.

10.4.2.2 Calculation Results

Max K_{eff} values calculated with 95% confidence level are provided in Table 10.19 for all casks used during SNF storage and transportation. Results of additional calculations for HI-STAR cask are given Table 10.20. Generally, the results confirm that neutron breeding coefficient (K_{eff}), with consideration of all calculation errors and uncertainties, with 95% confidence level, does not exceed 0.95 value at all conditions of normal operation, operational occurrences and accidents.

Results of the performed analysis of the nuclear safety of HI-STAR 190 transport systems and HI-STORM 190 storage systems for the spent nuclear fuel demonstrated provision of the subcriticality state at all normal conditions, operational occurrences and accident conditions. Analysis of the endless array of HI- STAR casks with various parameters of external and internal moderation demonstrates that maximum value of K_{eff} is significantly less than the established standard limit of 0.95.

Table 10.19 - **Max K_{eff} values for all casks used during SNF storage and transportation [136]**

FA	Enrichment, mass % ^{235}U	Maximum value $k_{эфф}$ [1]		
		HI-STAR	**HI-TRAC**	**HI-STORM**
MPC-31				
VVER-1000, FA-A	4.45	0.9449	0.9448	0.9434
VVER-1000, FA-M	4.45	0.9428	0.9435	0.9415
VVER-1000, FA-W	4.25	0.9387	0.9390	0.9378
VVER-1000, FA-W (LTA)	4.45	0.9420	0.9426	0.9409
MPC-85				
VVER-440, WC	4.45	0.8918	0.8924	0.8917
VVER-440, WC (2nd Gen)	4.65	0.9007	0.9007	0.8998

[1] "Maximum K_{eff} value" means the maximum possible effective neutron breeding coefficient with consideratio of the error, uncertainty and rated statistics, which is determined for most unfavorable combination of manufacture tolerances. Mean square deviation (σ) of the calculations is about 0.0003

Table 10.20 **- Results of additional K_{eff} calculations for HI-STAR [136]**

Configuration	% density of the internal moderator	% density of the external moderator	Max. Keff value
MPC-31			
Separate cask without reflector	100%	%	0.9449
Separate cask, full reflector	100%	100%	0.9447
Localizing shell, full reflector	100%	100%	0.9440
Separate cask with damages	0%	100%	0.4093
MPC-85			
Separate cask without reflector	100%	0%	0.9007
Separate cask, full reflector	100%	100%	0.9006
Localizing shell, full reflector	100%	100%	0.9000
Separate cask with damages	0%	100%	0.4071

More detailed justification of the subcriticality at normal operating conditions, operational occurrences and accidents is provided in PSAR.

10.5 Analysis of Thermal Conditions

According to requirements [39], Holtec International has performed thermal analysis [137] of HI-STAR 190 package and HI-STORM 190 storage system, which contain MPC with VVER SNF (the copy is enclosed in Volume 1.2.2).

10.5.1 Methods

During thermal analysis of HI-STAR 190 the document [137] made the following conservative assumptions:

- Absence of the contact between MPC fuel basket and shell as well as between the MPC shell and the cask, i.e. fuel basket and MPC are in a suspended state (have no contact).
- Convective heat transfer in the cask cavity was not considered.
- It was assumed that external surfaces absorb 100% of the solar energy falling onto them.
- Values of the heat conductivity of the materials of the shield protecting from neutron radiation, Metamic-HT and shock absorbing assemblies were significantly lowered.
- Heat transfer in axial direction via fuel pellets was not considered.
- Maximum design heat release was assumed in all SFA storage cells.
- Effect of the dust, fog, tilt angle and latitude, reducing impact of the sun heat flow was not considered.
- Conservative provision was that residual heat release of the SNF is unevenly distributed along the entire SFA length with maximum value in the middle of the active part length.
- Heat dissolution via the SFA spacer grids was not considered.

During thermal analysis of HI-STORM 190 the document [137] made the following conservative assumptions:

- Absence of the contact between MPC fuel basket and shell as well as between the MPC shell and the cask, i.e. fuel basket and MPC are in a suspended state (have no contact).
- It was assumed that external surfaces of the cask absorb 100% of the solar energy falling onto them. Shadowing of the cask surface by other neighboring casks was not considered.
- The assumption was that the bottom part of the cask is isolated.
- Heat transfer in axial direction via fuel pellets was not considered.
- Maximum design heat release was assumed in all SFA storage cells.

- Maximum hydraulic resistance was conservatively adopted during simulation of the flow via MPC.
- Conservative provision was that residual heat release of the SNF is unevenly distributed along the entire SFA length with maximum value in the middle of the active part length.
- Heat dissolution via the spacer grids and joining parts in the upper and lower parts of the cask was not considered.

10.5.2 Analysis Results

Analysis Results [137] for HI-STAR 190 are given in tables 10.21 – 10.25.

Table 10.21 - **Maximum temperature of the fuel shell for normal conditions of HI-STAR 190 transportation**

Cask	Temperature, °C	Temperature limit for normal operating conditions, °C
MPC-31	340	350
MPC-85	337	350

Table 10.22 - **Maximum values of the temperature for normal conditions of HI-STAR 190UA transportation for MPC-31 and MPC-85**

Material/Element	MPC-31 temperature, °C	MPC-85 temperature, °C
Fuel element cladding	340	337
Fuel basket	327	316
MPC shell	214	229
Neutron protection	151	156
Internal TPC shell	158	165
External TPC shell	126	130
Cover sealings	91	112
TPC cover	93	116
Shock absorber	83	72

Table 10.23 - **Maximum working pressure of HI-STAR 190**

Conditions	Excessive pressure, kPa.	
	MPC-31	MPC-85
Maximum working pressure in the MPC internal cavity		
Normal Operating Conditions	640.3	645.9
3% damage of FE	654.1	653.4
Ring gap between MPC and HI-STAR 190		
Normal Operating Conditions	190.2	173.0

Table 10.24 - **Maximum values of HI-STAR 190 elements temperature at a fire-associated hypothetic accident**

Material/Element	Initial condition, °C	Fire, °C
Fuel element cladding	340	340
Fuel basket	327	327

Material/Element	Initial condition, °C	Fire, °C
MPC shell	214	214
Internal TPC shell	158	172
Neutron protection	151	Not indicated as the neutron protection material integrity during or after the fire is not guaranteed
Cover sealings	91	106
TPC cover	93	102
External TPC shell	126	788

Table 10.25 - **Maximum pressure of HI-STAR 190UA transport cask at a fire-associated hypothetic accident**

Description	Excessive pressure, kPa.
Maximum working pressure in the MPC internal cavity	
Without FE damaging	683.1
100% damage of FE	1162.8
Ring gap between MPC and HI-STAR 190	
Pressure in the cavity	214.4

The document [137], for HI-STAR 190, with consideration of conservative assumptions, justifies non-exceedance of the maximum permissible temperatures of FE casings at normal operating conditions, opperational occurrences and design basis accidents. The same document proves non-exceedance of the design pressure limits and non-exceedance of the permissible temperature on external surfaces of HI-STAR 190.

Analysis Results [137] for HI-STORM 190 are given in tables 10.26 – 10.34.

Table 10.26 - **Maximum values of SFA FE casing temperature in HI-STORM 190 cask during storage**

Storage scenario	Temperature, °C	Temperature limits, °C
MPC-31	314	350
MPC-85	333	350

Table 10.27 - **Maximum temperatures in the MPC at long-term storage**

Element	Temperature, °C	
	MPC-31	MPC-85
Fuel cladding	314	333
Fuel basket	292	313
Basket support structures	241	269
MPC cover – average by section	231	225
Internal MPC shell	218	245
External MPC shell	203	224
MPC bottom – average by section	158	174

Table 10.28 - **Maximum HI-STORM 190 temperatures at long-term storage**

Element	Temperature, °C	
	MPC-31	**MPC-85**
Internal shell of the storage cask	147	163
External shell of the storage cask	81	81
Storage cask housing concrete:		
– Average by section	103	121
- Maximum	146	163
Storage cask cover concrete:		
– Average by section	108	121
- Maximum	121	141
Lower plate of the storage cask cover	121	142
Upper plate of the storage cask cover	83	83
Storage cask bottom – average by section	153	49

Table 10.29 - **Maximum HI-STORM 190 storage cask temperatures at the increased ambient temperatures**

Element	Temperature, °C	
	MPC-31	**MPC-85**
Fuel cladding	325	344
Fuel basket	303	324
Basket support structures	252	280
MPC cover – average by section	242	236
Internal MPC shell	229	256
External MPC shell	214	235
MPC bottom – average by section	169	185
Internal shell of the storage cask	158	174
External shell of the storage cask	92	92
Storage cask housing concrete	157	174
Storage cask cover concrete	132	152
Lower plate of the storage cask cover	132	153
Upper plate of the storage cask cover	94	96
Storage cask bottom – average by section	164	60

Table 10.30 - **Maximum HI-STORM 190 storage cask temperatures at the extreme ambient temperatures**

Element	Temperature, °C	
	MPC-31	**MPC-85**
Fuel cladding	326	345
Fuel basket	304	325
Basket support structures	253	281
MPC cover – average by section	243	237
Internal MPC shell	230	257
External MPC shell	215	236
MPC bottom – average by section	170	186
Internal shell of the storage cask	159	175

Element	Temperature, °C	
	MPC-31	MPC-85
External shell of the storage cask	93	93
Storage cask housing concrete	158	175
Storage cask cover concrete	133	153
Lower plate of the storage cask cover	133	153
Upper plate of the storage cask cover	95	97
Storage cask bottom – average by section	165	61

Table 10.31 - **Maximum HI-STORM 190 storage cask temperatures at 50% clogging of the vent inlets**

Element	Temperature, °C	
	MPC-31	MPC-85
Fuel cladding	319	338
Fuel basket	298	319
Basket support structures	247	275
MPC cover – average by section	237	231
Internal MPC shell	224	251
External MPC shell	210	231
MPC bottom – average by section	163	179
Internal shell of the storage cask	155	171
External shell of the storage cask	83	83
Storage cask housing concrete	154	171
Storage cask cover concrete	129	149
Lower plate of the storage cask cover	129	150
Upper plate of the storage cask cover	85	87
Storage cask bottom – average by section	159	55

Table 10.32 - **Maximum HI-STORM 190 storage cask temperatures at 100% clogging of the vent inlets**

Element	Temperature, °C	
	MPC-31	MPC-85
Fuel cladding	440	440
Fuel basket	428	429
Basket support structures	380	389
MPC cover – average by section	338	313
Internal MPC shell	359	368
External MPC shell	344	350
MPC bottom – average by section	298	293
Internal shell of the storage cask	307	307
External shell of the storage cask	158	142
Storage cask housing concrete	306	307
Storage cask cover concrete	210	215
Lower plate of the storage cask cover	211	218
Upper plate of the storage cask cover	112	104
Storage cask bottom – average by section	296	172

Table 10.33 - **Time of achievemen of the temperature limit for FE shell after beginning of the complete clogging of the vent inlets and outlets**

MPC type	Temperature, °C	Time of achievement of the temperature limit,
MPC-31	350	18.1
	440	82.0
MPC-85	350	9.0
	440	56.5

Table 10.34- **Pressure in the MPC at operational conditions**

Condition	**Average temperature across the MPC cavity volume, °C**		**Excessive pressure of the MPC cavity, kPa**	
	MPC-31	**MPC-85**	**MPC-31**	**MPC-85**
Long-term storage conditions: - Without FE damaging - At 1% damage of FE	 245 245	 259 259	 629.3 633.4	 648.6 651.4
Increased ambient temperature	256	270	644.4	664.5
Extreme ambient temperature	257	271	645.8	665.9
50% clogging of the vent inlets	251	266	637.6	659.0
Accident - 100% clogging of the vent inlets and outlets	380	375	819.6	812.7
Accident - 100% damage of FE	245	259	1076.0	891.9

The document [137] for HI-STORM 190 shows that calculated values of FE shell temperature values and the respective internal pressure in the MPC at normal operating conditions and at abnormal (50% clogging of the vent inlets) and accident conditions (100% clogging of the vent inlets) are below the permissible limits for temperature and pressure.

Mode detailed justification of the thermal conditions at normal operating conditions, operational occurrences and accidents is provided in PSAR.

10.6 Strength Analysis

Holtec has performed calculations to determine strength properties of HI-STAR 190 UA, HI-STORM 190 systems and auxiliary equipment utilized for transportation, storage and handling of the spent nuclear fuel at the CSFSF. Strength analysis outcomes are provided in the document [138] (the copy is enclosed in Volume 1.2.2).

The document [138] displays the following justifications:

- Assessment of the compliance of HI-STAR 190 package with the requirements of the documents [39, 123, 164] in terms of strength properties for normal transportation conditions and for hypothetic accident situations.
- Assessment of the preservation of the integrity of HI-STORM 190 storage cask (which determines tightness of the shell localizing the radioactive contents, assurance of the nuclear safety and radiation protection, as well as preservation of the possibility of the SNF extraction) under impact of all probable loads at normal operating conditions, operational occurrences and design basis accidents and extreme natural phenomena in accordance with the requirements of the documents [39, 123, 165].

- Assessment of preservation of integrity of the auxiliary equipment under normal operating conditions.

10.6.1 Methods

Analysis of HI-STAR 190 strength under PBPRM-2006, SSR-6 and Regulatory Guide 7.6 [123, 172, 174] was performed for normal accident operating conditions.

ANSYS Mechanical and LS-DYNA computer applications were used to perform strength and mechanical numerical calculations.

When analysing the strength of HI-STAR 190 UA and HI-STORM 190, the following main issues are considered:

- Determination of the strength characteristics of the casks and elements of the systems.
- Identification of materials used in the systems
- Determination of loads on the system elements during transportation and technological operations, at normal operating conditions, operational occurrences, accident situations and accidents. Determination of parameters of most unfavorable design conditions such as fire or water submersion.
- Determination of the criteria of permissibility of the systems behavior under impact of the specified various operating conditions on the basis of ASME standard criteria and criteria of other regulatory documents.
- Determination of the margin of strength and safety of the systems under impact of the loads at various operating conditions.

When analysing the strength of safety critical auxiliary equipment, the following main issues are considered:

- Strength properties of the auxiliary equipment.
- Determination of loads acting on auxiliary equipment under normal operating conditions.
- Determination of the criteria of acceptability of operation of the auxiliary equipment at normal conditions in accordance with ASME standard and other standards.
- Analysis to determine the margin of strength of the auxiliary equipment at normal operating conditions.

10.6.2 Analysis Results

Performed analyses [139] resulted in justification that equipment used at the SNF handling will preserve its functionality throughout the entire design service life, at all design modes.

Results provided in [139] show that HI-STAR 190 UA complies with requirements of par.659, 727 and 729 of SSR-6 and PBRM-2006 standard. Results of the simulation of falling from 9-meter height are performed with the use of the upper limit value of the production tolerance for aluminum material of the cellular structure (i.e. 110% of the nominal value), to ensure maximum value of braking during the impact. During assessment, values of the shock absorbers collapse strength were reduced to 90% of the respective nominal values in order to check that lower limit value of the production tolerance will not result in ‘failure’ of the shock absorber due to extensive displacements at the collapse. Considered were also 2 penetration events and determined consequences.

For conditions of hypothetic accident at transportation all reliability coefficients are over 1.0, tightness function was preserved for all postulated events. Respectively, at hypothetic accident conditions of transportation HI-STAR 190 UA has sufficient strength to satisfy requirements SSR-6 and PBRM-2006 documents as to subcriticality, tightness, protection and temperature.

HI-STAR 190 UA and MPC containments are preserved tight and sealed in case of submersion in accordance with par.733 of SSR-6 and PBRM-2006, which follows the free falling, perforation and fire.

Opening between the cover and flange will be sealed by 2 sealings in completely pressed state.

Average warping of the basket panel in the fuel zone is less than the standard limit.

Local plastic deformation in case of penetrating concentrated impact from a soft steel rod will lead to a surface dent and not to a deep penetration, and will not be a cause of the loss of integrity of the protective shell.

More detailed description of the strength analysis at normal operating conditions, opperational occurrences and accidents is provided in PSAR.

10.7 Radiation Safety

Actions to ensure radiation safety at all stages of the CSFSF operation come down to assurance of the safety at normal operation and at accidents.

Observance of the RS principles is achieved through selection of optimal technical solutions and performance at all stages of the CSFSF life cycle (construction, commissioning, operation and decommissioning) of the set of actions on radiation protection. These actions can be conditionally divided into the following groups:

- technical (shielding, dust suppression, decontamination, active ventilation and active gas treatment, use of remotedly controlled mechanisms, CCTV etc.);
- radiation and hygienic (establishment of the sanitary and protection zone and surveillance zone, establishment of the reference levels, assessment of personnel exposure doses, premises and territory planning, airlocks, use of PPE and PRPE, radiation control etc.);
- organizational (preparation of workplaces, permit to perform works, control and supervision of teh activity, organization of medical aid etc.).

The list of exact actions/measures is developed and regulated for each stage of the CSFSF life cycle:

- by the design documentation to include construction design, instructions and provisions of the Exclusion Zone - CSFSF construction phase;
- program of putting into operation, commissioning program, instructions and provisions of the Exclusion Zone - CSFSF commissioning phase;
- operation and technical documents and technological regulation of the CSFSF, as well as the Manual on the RW Handling of the Exclusion Zone - operation phase;
- by the CSFSF decommissioning program, instructions and provisions of the Exclusion Zone - decommissioning phase.

Further, in the following sections there is detailed description of the actions to ensure radiation safety adopted in the design for all stages of the CSFSF life cycle.

Detailed justification of the radiation safety is provided in PSAR.

10.7.1 Radiation Safety at Construction

The CSFSF construction will be carried out on the territory of the exclusion zone and compulsory evacuation zone (Exclusion zone) which is characterized by the radioactive pollution caused by the consequences of the Chernobyl accident in 1986. In this area valid are reference levels [112], which shall be considered when planning the measures related with the CSFSF construction and operation.

In order to improve the radiation safety in accordance with [112], the exclusion zone is divided into three radiation-regime zones, namely:

- Zone I (the 10-kilometer zone) — the area within a 10-km radius around the Chernobyl Nuclear Power Plant. In this area, the radiation-hazardous works are carried out on the basis of programs agreed with the regulatory authorities in accordance with the requirements of the current normative-legal acts on radiation safety in Ukraine. The strict radiation monitoring procedures are implemented in this zone.
- Zone II (the buffer zone) — the territory from the border of the 10-kilometer zone to the outer edge of the exclusion zone (except the city of Chernobyl). In this area, constant radiation monitoring is implemented.
- Zone III (the residential zone) — this zone comprises a part of the territory of Chernobyl and the surrounding sites where there are dormitories and administrative building of the State Agency of Ukraine for the Exclusion Zone Management, the public catering facilities and retail outlets, the social, cultural, health-care institutions, and the access roads.

The CSFSF construction site is located in Zone I, its territory is almost completely occupied by the pine forest (forest occupies 17.2 hectares out of 18.2 ha).

During construction of the CSFSF, radiation exposure of the personnel are primarily related with the preliminary preparation of the construction site which area refers to the radiation contaminated lands. The following works are provided for during preparation of the construction site:

- arrangement of fire protection lines along the perimeter of the construction site occupied by the forest;
- removal of the forest plantation to include removal of trees and underwood, logging of the cut timber, stump extraction and removal of the remaining roots (area - 17.2 ha);
- removal of the upper soil layer with organic inclusions to a depth of 0.2 m, with further transportation to the storage site (area - 18.2 ha);
- planning of the territory with consideration of the soil mass balance and removal of the excessive soil to backfill the basis of the access railroad;
- planning of the territory for construction of the access motor road to the construction site)
- construction of the access railroad from Shepelichi station to the construction site;
- arrangement of the fencing along the perimeter of the site and construction of the checkpoint.

The site area is currently slightly slopy from north to south and is characterized by altitudes from 142.00 to 139.00 m in the northern part and from 138.50 to 137.00 m in the south.

Organization of the relief anticipates for the entire leveling of the territory. Estimated grade elevation of the site is 138.50 m.

Forest cut down during the preparation of the site territory does not refer to radioactive wastes, requires no burial and will be transferred to a specialized organization for the use within the 10-km zone.

During preparation of the CSFSF site territory the works, which by its complexity are divided into characteristic groups, are performed. List of the works is given in tables in Table 10.35.

Table 10.35 – **List of the performed works with breakdown to typical groups [148]**

Groups of works	**List of performed works**
Works performed in the contaminated territory of the CSFSF site, which do not anticipate active impact on radiactively contaminated soil.	• removal of the forest plantation to include removal of trees and underwood; • arrangement of the fencing along the perimeter of the site; • erection of temporary contractor's buildings.
Works performed in the contaminated territory of the CSFSF site, which do anticipate active impact on radiactively contaminated soil	• arrangement of fire protection lines along the perimeter of the construction site occupied by the forest; • logging of the cut timber, and stump extraction; • removal of the upper soil layer with organic inclusions to a depth of 0.2 m, with further transportation; • planning of the territory with consideration of the soil mass balance (to include removal of the excessive soil to backfill the base of the access railroad); • planning of the territory for construction of the access motor road to the construction site; • planning of the territory for construction of the on-site railway tracks; • planning of the territory of the access railroad from Shepelichi station to the construction site; • installation of poles/supports for the fencing along the perimeter of the site; • construction of the checkpoint.

Division of the works into typical groups enables differentiated approach to selection of measures aimed at protection of the personnel and environment.

So, for works with active impact on radioactively contaminated soil, use of additional PPE is required (protection from the personnel inhalation exposure), measures on dust suppression (protection of the personnel and environment) and control of radioactive contamination of the air on the construction site borders (environmental protection).

According to [149], hygienic classification of labor by working process complexity values at performance of preparatory works on the CSFSF construction site will be classified as Class 2 (admissible labor conditions).

During performance of these works possible is short-term increase of the volume concentration of radionuclides in the near-surface layer of the atmosphere for account of dust lifting, what will lead to the building personnel radiation exposure and additional surface contamination of adjacent areas, to include motor roads and neighboring facilities, first of all - Vektor CPS. Considering the fact that the entire adjacent territory is radioactively contaminated in the same extent as the earthwork sites, no significant additional contamination of this territory will occur.

Since the main scope of construction works will be performed on already decontaminated construction site, no further radiation exposure during construction is assumed. Decontamination of the construction site before the main scope of the construction works means the entire scope of works on preparation of the site, which also anticipate removal of the soil for the purpose of creation of the grade elevation of the CSFSF site.

Detailed description of the organization of works during construction is provided in Volume 11 (Organization of Construction) of the present design.

10.7.1.1 Radiation situation and radiation exposure sources

Main source of the personnel radiation exposure during construction of the CSFSF is radioactive contamination of the construction site which is determined by gamma radiation dose rate, radioactive contamination of the soil cover and plantations, as well as the near-surface layer of the atmosphere.

Gamma radiation dose rate

Gamma radiation dose rate on the CSFSF construction site and adjacent territory is primarily generated by the radioactively contaminated soil and determined by the $_{137}$Cs radiation. Contribution of $_{137}$Cs that has migrated into other environments (air, water, biological objects) is insignificant [148, 150] мигрировавшего в другие среды (воздух, вода, биологические объекты), незначителен [148, 150].

The document [148] provides results of gamma radiation dose rate measurements on the CSFSF construction site. Gamma radiation dose rate measurement was performed by the grid of 25x25 m at the height of 1m and 0.1m with use of MKS-07 “Poisk” dose rate meter.

Gamma surveying revealed areas with increased (abnormal) values of the dose rates. In this areas gamma radiation dose rate was measured by the grid of 10x10 m at the height of 1m and 0.1m. Figure 10.1 shows the map of the EDR distribution at 1-m height (left) and 0.1-m height (right).

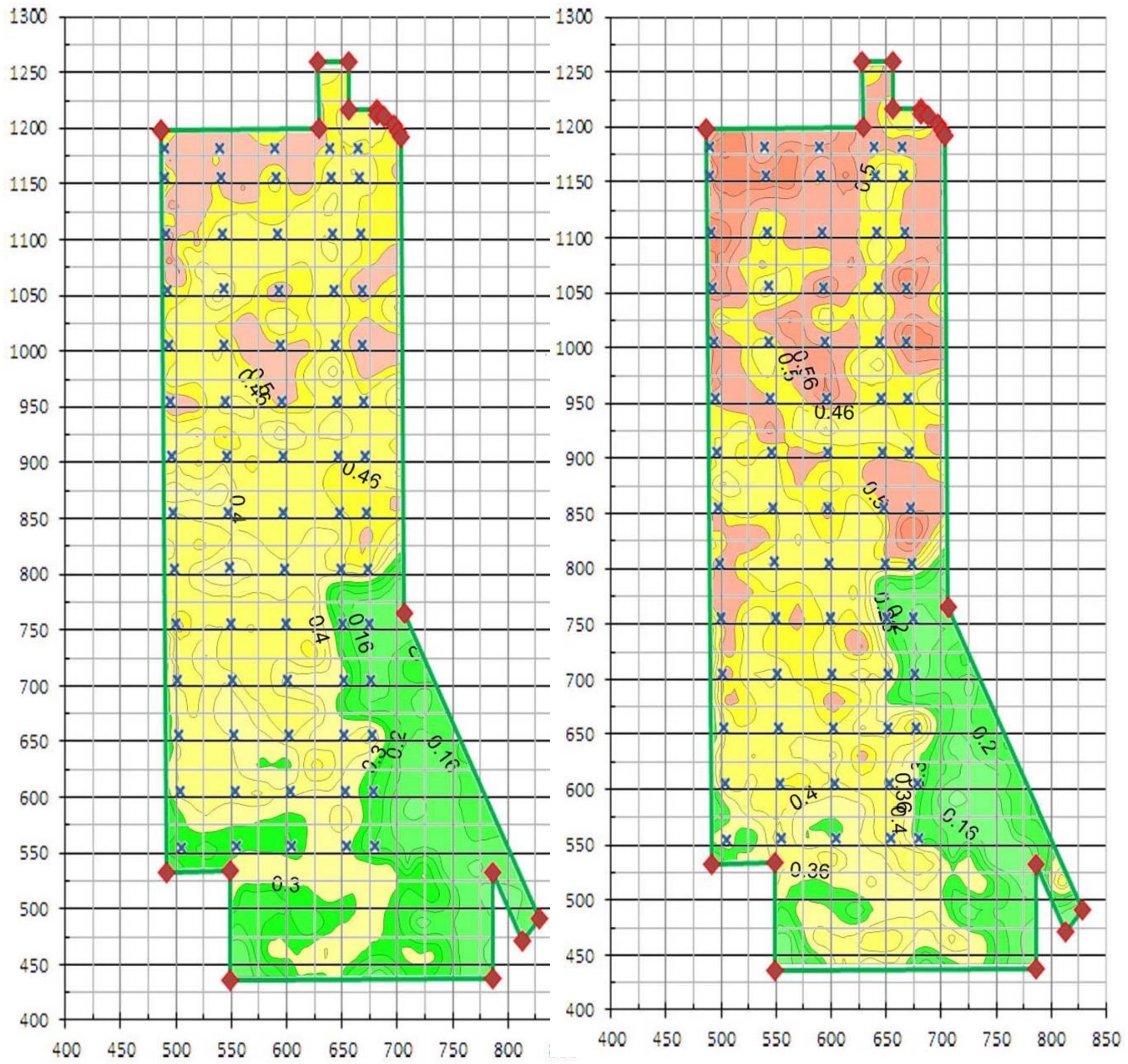

Figure 10.1 - Interpretative map of EDR distribution at the height of 1 m (left) and 0.1 m (right) on the CSFSF construction site

After analyzing the map data, the following conclusions can be made [148]:

- EDR decreases with increase of the distance from the soil;
- Maximum EDR value equals to 0.70 mcSv/h at the height of 0.1 m and 0.66 mcSv/h at the height of 1 m;
- Average EDR value on the site equals to 0.41 mcSv/h at the height of 0.1 m and 0.37 mcSv/h at the height of 1 m;
- area of the site with the EDR exceeding 0.5 mcSv/h is relatively small and concentrated mainly near the northern border of the site.

Radiation contamination of the soil cover

Emergency radioactive contamination of soils in the exclusion zone is represented by the mix of radionuclides ^{90}Sr, ^{137}Cs, ^{154}Eu, $^{238-241}Pu$ and ^{241}Am, which are in various physical and chemical forms and relations [148].

Currently, in most landscape conditions 90 to 95% of the total activity of accidental contamination is concentrated at the depth of 5-10 cm from the soil surface [148].

The document [148] provides results of contamination density measurements of the soil cover on the CSFSF construction site.

According to the data [148] shown in Figures 10.2 and 10.3, density of ^{90}Sr contamination in the entire area of the construction site does not exceed 40 kBq/m^2, and density of ^{137}Cs contamination near three borders of the site exceeds 80 kBq/m^2. Distribution of the density of the surface contamination of TUE in the area of the CSFSF construction site is displayed in Figure 10.2

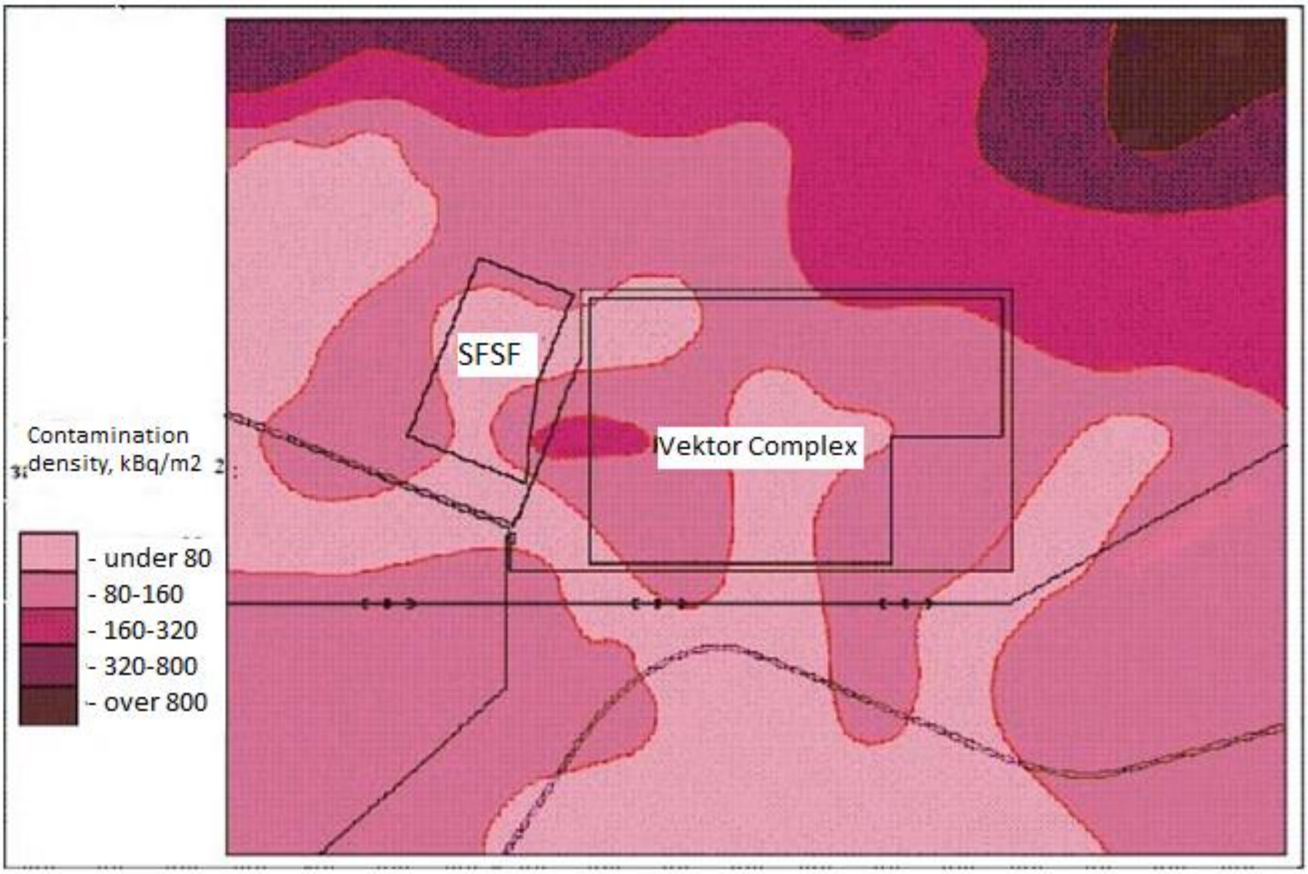

Figure 10.2 - **Density of the surface ^{137}Cs contamination**

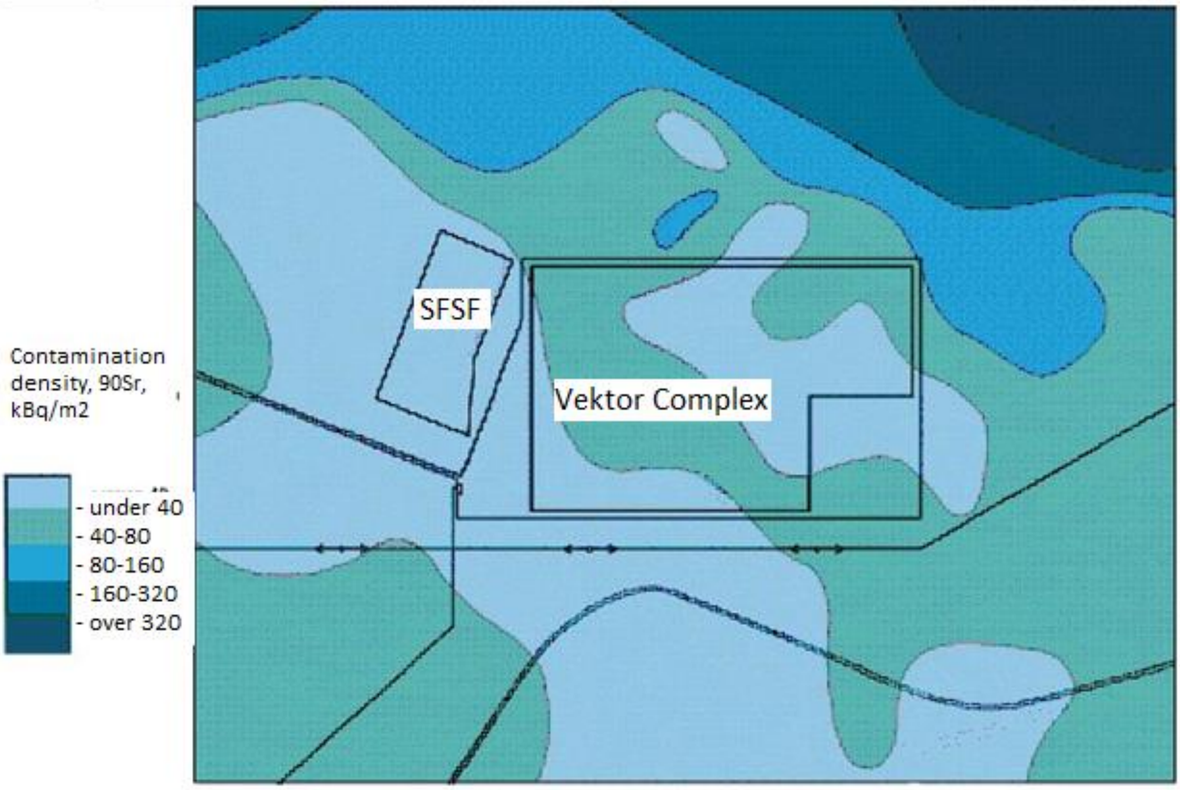

Figure 10.3 - **Density of the surface ^{90}Sr contamination**

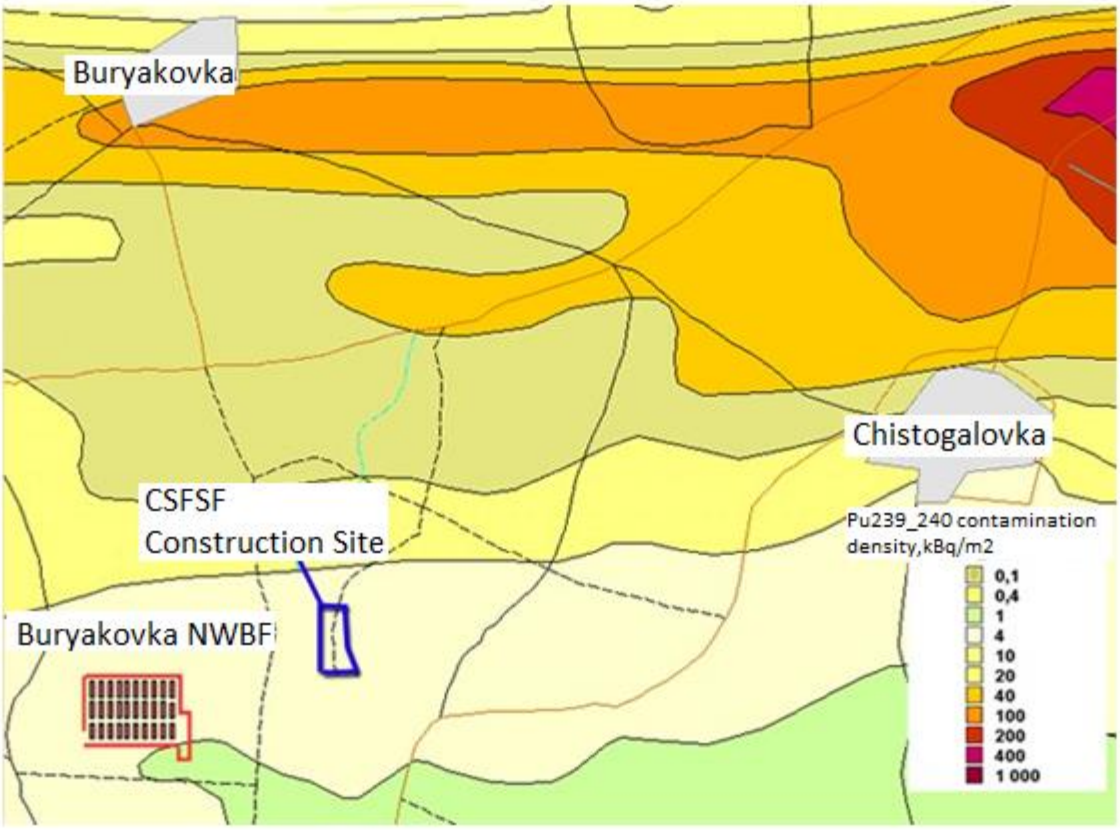

Figure 10.4 - **Density of the surface $^{239, 240}$Pu contamination of the CSFSF construction site area**

According to the results of the measurements [148], the beta-particles flux density on the territory of the site does not exceed 120 ppm cm^{-2} min^{-1}. Most often values are within the scope of 50 – 80 ppm·cm^{-2}·min^{-1}.

The average specific activity of ^{137}Cs and ^{90}Sr in the survey area, in accordance with the results of determination of the specific activity of these radionuclides, for the 20-centiimeter soil layer does not exceed 2.35 kBq/kg and 1.36 kBq/kg respectively. In the most contaminated area, the values are around 3 kBq/kg and 2 kBq/kg respectively.

According to the document [148], values of the specific activity of beta-, gamma emitting radionuclides do not exceed the level of extraction - 10 kBq/kg, and values of the specific activity of transuranium alpha-emitting radionuclides do not exceed the level of extaction - 0.1 kBq/kg, which are established by the state sanitary rules [110]. Therefore, at 20-cm thickness of the removed soil the wastes formed as a result are not radioactive.

Radioactive pollution of the boundary layer of the atmosphere

The existing radioactive pollution of the atmosphere [148] within the exclusion zone is formed due to the secondary air migration of radioactive accidental precipitations of 1986, which are deposited in various natural and man-made objects. In this case value of the volume-specific activity of the boundary layer of the atmosphere is formed under impact of multiple factors, having natural or natural and man-made origin. Most significant of them are the following influencing factors:

- current weather (wind speed, precipitations) and season;
- man-induced activity causing the dust lifting;
- density of the surface contamination of the soil cover in the area;
- radionuclide, physical and chemical and dispersion composition of the primary accidental radioactive fallout;
- relief of the neighboring terrain;
- properties and current state of the soil cover;
- dangerous natural and natural and man-induced phenomena (forest fires, turf deposit combustion, dust storms etc.).

In each certain situation, significance of any of the above factors for formation of the magnitude of the air pollution may vary significantly, what leads to a high dynamics of the values of radioactive pollution of the air in time and space.

At the present time [148], the main factor facilitating the increase of the level of radioactive pollution of the air is man-induced activity within the exclusion zone.

According to the data provided in [148] under results of the research conducted on the CSFSF site, the following concentrations of long-lived radionuclides of the Chernobyl origin (^{137}Cs, ^{90}Sr+^{90}Y) in the boundary layer of the atmosphere:

- $2.3 \cdot 10^{-5} \pm 5.3 \cdot 10^{-5}$ Bq/m^3 (measurements of 28.10.2014);
- $4.5 \cdot 10^{-5} \pm 1.2 \cdot 10^{-5}$ Bq/m^3 (measurements of 4.11.2014).

Obtained results do not exceed the reference levels established by appropriate regulation [112].

Radioactive contamination of the vegetation

The CSFSF construction area is almost completely occupied by the pine forest. The document [148] provides results of radioactive contamination of timber on the CSFSF construction site. According to the data[148], surface contamination does not exceed: bark - 118 beta-particles/cm^2 min, debarked timber – 25 beta-particles/cm^2 min, trunk section – 38 beta-particles/cm^2 min. Specific activity of the timber does not exceed 1.2 Bq/kg.

According to the criteria laid down in the document [110], unbarked timber on the CSFSF construction site does not refer to the radioactive waste by the exemption level for beta- and gamma-emitting radionuclides of Group 3 (10 kBq/kg).

According to the criteria laid down in the regulatory document [112], timber to be obtained after removal of the forest on the CSFSF construction site does not exceed the reference levels of radioactive contamination for their limited release and use in the industry.

10.7.1.2 Normal conditions of the construction

Calculation of the personnel exposure doses was performed in accordance with the document [151] approved by the Ministry of Public Health of Ukraine in 2004.

Choice of this method for assessment of the personnel dose loads during preparatory works on the CSFSF construction site is conditioned by the point that nature of this site contamination almost doesn’t differ from the similar characteristics for the materials localized near the Shelter Facility and on the adjacent territory.

The following information (for each operation) was used as initial data for calculation of the personnel dose loads:

- labor costs (manhours quantity);
- activity type;
- radiation situation in the WA;
- category of the performed works by physical load;
- calculated values, IAW regulatory documents (geometry of external exposure, coefficient of transition from expositional dose of the external exposure to the effective dose of the external exposure, type of the used PRPE and their corresponding value of the effective protection coefficient - kEP);
- coefficient “effective dose rate per unit of total concentration of beta-nuclides in the air”.

Data on the radiation situation in the work performance areas are shown in Chapter 10.7.1.1.

Description of the parameters used at calculations, and their values, are given in Table 10.36.

The calculation used averaged value of the dose rate for operations which labor efforts were evenly distributed in the work performance areas. In this case more sophisticated detalization of the work episodes will not lead to significant change of the results of calculation of collective and individual exposure doses of the personnel.

Averaged EDR values for specific types of works are given in Table 10.37.

The design collective effective dose of the personnel external exposure was determined by the formula:

$$SP = K_{DM} \times K_E \times EDR \times T_{RHC}, \text{ man.-mSv,} \quad (10.1)$$

where K_{DM} – design margin coefficient;

K_E - coefficient of transition from expositional dose of the external exposure to the effective dose of the external exposure, mSv/R;

EDR - design value of expositional dose rate of the external exposure in the work area, R/h;

T_{RHC} – labor efforts for performance of a certain type of works in radiation hazardous conditions, man-hours.

The design collective effective dose of the personnel internal exposure was determined by the formula:

$S_{inhal} = (K_{DM} \times g_{E\beta} \times C_\beta \times T_{RHC})/K_{EP}$, man-mSv, (10.2)

where K_{DM} and T_{RHC} – see formula 10.1;

K_{EP} - effective protection coefficient if PRPE is used;

C_β – averaged value of the total concentration of beta-emitting radionuclides in the work area zone, Bq/m^3;

$g_{E\beta}$ - coefficient “effective dose rate per unit of total concentration of beta-nuclides in the air”, mSv*h$^{-1}\cdot$Bq$^{-1}\cdot$m^3. Values of this coefficient are adopted IAW the methodology approved by the Ministry of Public Health of Ukraine, for typical characteristics of the Shelter Facility aerosols [151] determined depending on the category of works. Choice of the category of works under the design depends on the degree of physical load and is made in accordance with the Order of the Ministry of Public Health of Ukraine no.248 of 08.04.2014 [149].

Table 10.36 **– Values of the parameters adopted during calculation of the current exposure doses**

Parameters considered at calculation of doses	Adopted values
Design margin coefficient, K_{DM};	2
Coefficient of the labor effors at increase of PRPE use, K_{IT}	1.1 - at the use of semi-facial filtering respiratory mask (earthworks and for the personnel in cabines of the building machinery)
Coefficient of transition from expositional dose of the external exposure to the effective dose of the external exposure, mSv/R	11 - for all activity
Averaged value of the total concentration of beta-emitting radionuclides in the work area zone (according to Chapter 4 hereof)	0.0011 Bq/m^3 1)
Effective protection coefficient of PRPE, K_{EP}	K_{EP} = 20
Complexity category 2) of the performed works (by complexity)	Cat II
Coefficient “effective dose rate per unit of total concentration of beta-nuclides in the air”, (mSv·m^3)/(m·Bq)	$1.4\cdot10^{-3}$ – for Cat II works and ‘typical’ characteristics of aerosols
Reference level of the single-time (shift) individual dose , RL_S, mSv/shift	under 0.08 mSv - for all works 3)

1) According to data [“Reference on the Radiation Condition of the Environment in the Exclusion Zone in December 2012”, Chernobyl Spetskombinat SE”], the maximum value of the volumic activity of ^{137}Cs in the boundary layer of the atmosphere at ARMS checkpoint no.38 in the territory of NWBF “Buryakovka”.

2) Cat II works (physical works of medium complexity) are works associated with walking, relocation or carriage of loads under 10 kg in the standing or sitting position, and accompanied by moderate physical stress (reference energy costs of a man are within 175-290 W).

3) Shift is 10 hours

Labor efforts for performance of a certain type of works in radiation hazardous conditions (T_{RHC}) were determined by formula:

$T_{RHC} = T \times K_{UT}$, man.-h, (10.3)

where T - labor efforts for performance of a certain type of works (without considering the specifics of the works in radioactive contamination conditions);

K_{UT} – coefficient that accounts increase of labor efforts in case PRPE is used.

Duration of the work performance (tP) was determined by formula:

$t_P = T_{RHC} / N_{TM}$, h, (10.4)

where N_{TM} - number of workers in one team.

Total number of workers' teams (n) necessary for performance of a certain work is determined based on the values of reference levels of the shift exposure dose with rounding to the higher side:

$n = (S_P + S_{inhal})/(RL_S \times N_{TM})$, (10.5)

where RL_S – reference level of the shift exposure dose.

Total number of the workers participation for performance of a certain work (NTOT) was determined according to formula:

$N_{TOT} = N_{TM} \times n$, man.-part. (10.6)

Actual duration of one team work (t_{TM}) was determined by formula: $t_{TM} = t_P / n$, h (10.7)

Collective effective dose of the personnel exposure at performance of a certain work was determined by the formula:

$S_{TOT} = S_P + S_{inhal}$, man.-mSv. (10.8)

Planned individual single-time (shift) dose of one worker exposure at performance of a certain work with consideration of the dose received on the way to the workplace and back (E_0) was determined by formula:

$E_0 = S_{TOT} / N_{TOT}$, mSv. (10.9)

Assessment of the collective and individual doses of the personnel internal and external exposure was performed on the basis of the methodology [151].

Results of assessment of the personnel dose loads at performance of works on preparation of the site to the CSFSF construction are given in table 10.37.

As a result of the performed calculation on the labor efforts and collective effective exposure dose of the personnel participating in the CSFSF construction site preparatory works the following final data were obtained:

- number of man.- participations over the entire period of works – 10167;
- total labor input - 84282 man-hours;
- total collective effective dose of the personnel exposure was about 146 men-mSv of which inhalation component (internal exposure) is less than 1%.

Analysis of the performed calculations displays that reference levels of the personnel exposure will not be exceeded during works on preparation of the CSFSF construction site.

132

Table 10.37 - **Results of assessment of the personnel dose loads at performance of preparatory works on the CSFSF construction site**

Description of works	Scope of works		T, man-hours	KUT	Trhc, man-hours	Ntm persons	tR, hours	EDR on RM, R/h	SR, man-mSv	n, particip	ttm, hours	Ntot man-particip	Sinhal, man-mSv	T, days	Ttot, man-hours	Stot, man-mSv	Eo, mSv	RL ind., mSv
	UoM	Qty																
Forest clearing with stump extraction	pcs/ha	23492/ 18.7	28747	1.1	31621.7	30	1054	4E-05	27.8	106	10	3180	1E-01	105.4	31621,7	27.924	0.009	0.08
Removal of the technogenic soil layer, 0.2m thick	ha/m^3	18.7/ 34516	1540	1.1	1694.0	4	424	4E-05	1.5	43	10	172	3E-04	42.4	1694.0	1.491	0.009	0.08
Planning of the territory with backfilling, soil compaction in the fill, and strengthening of slopes	m^3/m^2	91893 / 175750	5928	1.1	6520.8	8	815	4E-05	5.7	82	10	656	1E-03	81.5	6520.8	5.739	0.009	0.08
Arrangement of reinforced concrete fencing of the territory	m	1950	7552	1.1	8307.2	7	1187	4E-05	7.3	119	10	833	1E-03	118.7	8307.2	7.312	0.009	0.08
Construction of access onsite and temporary onsite motor roads, walkways	km	3	7983	1.1	8781.3	8	1098	4E-05	14.539	110	10	880	1E-03	109.8	8781.3	14.541	0.017	0.08
Laying of temporary water supply systems of steel pipes	m	1271	5906	1.1	6496.6	11	591	4E-05	1.454	60	10	660	2E-02	59.1	6496.6	1.474	0.002	0.08
Arrangement of temporary domestic sewage system utilities and construction of the septic tank (V=15m3)	m	139	1199	1.1	1318.9	7	188	4E-05	15.993	77	2	539	4E-03	18.8	1318.9	15.997	0.030	0.08
Arrangement of temporary onsite networks of fire water supply systems and construction of fire water reservoirs (V=3x80 m3)	m	228	2129	1.1	2341.9	7	335	4E-05	17.45	84	4	588	7E-03	33.5	2341.9	17.454	0.030	0.08
Arrangement of temporary off- and onsite power supply networks and installation of transformer substation	km	1.3	1846	1.1	2030.6	11	185	4E-05	33.44	102	2	1122	6E-03	18.5	2030.6	33.447	0.030	0.08
Arrangement of temporary networks of outdoor lighting of motor roads and security lighting of the site	km	7.5	9717	1.1	10688.7	11	972	4E-05	9.4	98	10	1078	3E-02	97.2	10688.7	9.439	0.009	0.08
Assembly of the module unit of the checkpoint, 3.0 t weight, pcs, with arrangement of foundations of concrete slabs (12 pcs)	pcs.	1	143	1.1	157.3	5	31	4E-05	0.1	4	8	20	5E-04	3.1	157.3	0.139	0.007	0.08
Assembly of the sanitary and amenities buildings (4 pcs) of module units, 4.5 t weight, with arrangement of foundations of concrete slabs (100 pcs)	pcs.	24	1189	1.1	1307.9	7	187	4E-05	1.2	19	10	133	4E-03	18.7	1307.9	1.155	0.009	0.08
Construction of warehouse premises	m^2	288	2741	1.1	3015.1	9	335	4E-05	2.7	34	10	306	9E-03	33.5	3015.1	2.663	0.009	0.08
Sub-total			76620		84282				139			10167	0.186		84282	138.8		
Control and supervision, 5%			3831.0		4214.1				6.9			508.4	0.009		4214.1	6.9		
Total:			80451		88496				145.5			10675	0.195		88496	145.7		

10.7.1.3 Measures to Ensure Radiation Safety While Building CSFSF

Radiation protection of the personnel during performance of works on preparation of the CSFSF construction site is ensured by a set of organizational, radiation-sanitary and technical measures.

Organizational Arrangements

To ensure the proper level of radiation safety, the following arrangements are planned the project:

- human resource training;
- providing for safety of work;
- monitoring and supervision during performance of works.

The personnel performing the works on the territory of the exclusion zone is subject to high external and internal exposure due accidental radioactive contamination of the surrounding environment, and in accordance with [112] is classified as Category A staff.

In accordance with the requirements of [152], the following persons are permitted to work within RZ&CRZ:

- persons aged 18 and older who do not have medical contraindications for wok in contact with the ionizing radiation sources (IRS) or causation of disease and disability to the previously performed works on liquidation of consequences of the Chernobyl accident;
- the personnel who have received instruction, training and passed testing of knowledge of RS, OS and FS within the scope of their job descriptions and qualifications.

Specific arrangements providing for radiation safety during works are as follows:

- appointment of persons responsible for the safety of operations;
- briefings on RB, OS and FS;
- organization and monitoring of the use of PPE (including RPE);
- issuing permits for works and supervision of safety of works;
- registering breaks and end of work;
- maintenance and timely repair of equipment involved in the implementation of the project.

It should be noted that production of permit to perform works on the CSFSF construction site is not necessary, because the radiation conditions in the WA do not meet the established criteria of particularly dangerous works as regards the radiation dose rate (DR) (MD does not exceed 12 mSv/h) [152].

The monitoring and supervision of compliance with the RS, FS and OS regulations are carried out by the Customer’s and Contractor’s compliance supervision services, within their competences, in accordance with the laws of Ukraine and applicable regulations.

Radiation-Hygienic And Technical Measures

To ensure the appropriate level of RS during the work on preparation of the CSFSF construction site, the following activities are planned:

- dosimetry and medical monitoring of personnel;
- use of personal protective equipment (PPE), including respiratory protective equipment (RPE);

- organization of sanitary access control;
- dust suppression and decontamination.

Radiation monitoring is an integral part of the entire system of RS in the course of project implementation.

Personal dosimetry monitoring implies:

- monitoring the radiation situation, including:
  - monitoring of DER in the WA, temporary buildings and traffic routes;
  - monitoring of radioactive contamination of the equipment, vehicles, internal surfaces of temporary structures;
  - monitoring of volume activity of radioactive substances in the air in the working areas during execution of works;
  - monitoring of the volume activity of radioactive substances in the air at the border of the CSFSF construction site during felling and earthworks;
- control of contamination of the PPE and skin;
- personal dosimetric monitoring (IDM) of the personnel, including:
  - PDM of external exposure;
  - PDM of internal exposure;
- radiation monitoring during handling of radioactively contaminated materials and structures.

Medical services and rehabilitation of the personnel involved in the works include:

- medical examinations;
- first medical aid;
- disease prevention and treatment (if necessary);
- rehabilitation procedures (if necessary).

Medical examination of personnel and first aid will be available in SOHF-126 (Chernobyl). The workers' locker rooms located on-site in the trailers must be equipped with places with first aid kits.

According to the requirements of [152], the work in the exclusion zone are permitted only with the use of appropriate personal protective equipment. The staff is dressed in overalls, while the personal clothing is stored in the on-site dormitory (Chernobyl). Working in personal working clothing is strictly prohibited.

The personnel involved in the project will be provided with basic and additional PPE, including the sets of protective clothing and footwear for work and travel.

The content of the basic set of personal protective equipment is regulated by Cl. 3.9 of [152]. The basic set of PPE includes:

- cotton coveralls;
- headdress;
- cotton underwear;
- cotton socks;
- shoes;
- sweatshirt or jacket (depending on the weather conditions).

Additional PPE include:

- plastic protective clothing (sleeves, aprons, shoe covers, splash coats, bib and brace overalls, etc.);
- gloves (rubber, vinyl chloride, cotton);
- various helmets and protective goggles;

- hearing protection equipment and RPE.

Selection of additional PPE is dependent on the type of activity.

Furthermore, according to Paragraph 3.9.5 of [152], during travel from the place of residence (city Chernobyl) to the place of execution of works the personnel will use the transport kit of PPE, which must be marked with letter "T" (transport clothes) on the left side of the upper garment. The working kit of basic PPE should be marked with letter "P".

Compliance with these requirements and proper monitoring will provide for sufficient level of protection from radiation effects on the organs of hearing, respiratory, and skin of the workers.

Felling and earthworks on the CSFSF construction site are the works with open sources of ionizing radiation that imply the providing of temporary (for the period of preparation of the CSFSF site) sanitary inspection station, which should provide for the following:

- dressing rooms for the personnel and temporary (during the work shift) storage for the transport clothes;
- storage of clean sets of working clothes and other personal protective equipment;
- place for intermediate storage of contaminated clothing and used disposable PPEs before dispatch to the laundry (for deactivation) or for disposal;
- equipped room for washing (decontamination) hands and other exposed parts of the body;
- storage for bottled drinking water.

The project provides for the organization of temporary sanitary inspection station on the basis of semi-detached residential trailers, divided into two parts — "clean" and "dirty" — with a vestibule with small a washing trailer in between. The staff will pass the temporary sanitary inspection station, leave the transport clothing in the "clean" part, and pass through the sanitary barrier to the "dirty" part to put on the working clothing and additional PPE. In the reverse direction, from the "dirty" part to the "clean” part, the staff will be provided with the opportunity to wash the open skin (hands and face) in the attached washing trailer with the water supply system and the waste water collector.

The project provides for the monitoring of radioactive contamination of clothing and the body surface of the personnel at the radiation monitoring station provided. The radiation monitoring station will be located in a separate residential trailer adapted for this purpose. If the contamination levels of personal clothing and footwear exceed the established threshold, they are subject to decontamination, and in case decontamination is impossible, they are disposed of under certificate.

Radiation monitoring of vehicles and cargoes will be carried out at the dosimetry monitoring stations (DMS) when traveling beyond the borders of the first and second zones — "Lelev" and a “Dytyatki", respectively. If necessary, pursuant to the provisions of [152], decontamination of vehicles is carried out at the sanitization station "Lelev" (SS "Lelev"). In addition, the Contractor, on a contractual basis, can perform decontamination of vehicles at the facilities of enterprises located near the CSFSF construction site (Complex "Vector" and NWBF “Buryakovka”).

Exit of vehicles from the exclusion zone is carried out with mandatory radiation monitoring on the DMS "Dityatki" and is allowed only if the the established clearance radiation level is not exceeded.

Loads transported outside the exclusion zone shall be subject to mandatory radiation monitoring and registration.

Dust suppression is the most effective measure to minimize the generation of radioactive aerosols in the air in the working areas.

The need for dust suppression in the WA, as well as its frequency and amounts are determined by the types of activity, season and current weather conditions (rain, wind, etc.). Various formulations are used, depending on the desired period of dust control.

Dust suppression is provided for in the performance of works related to high dusting — hauling cut trees, uprooting stumps, grading the surface of construction plots and other earthworks. Depending on the initial situation, the dust control may be performed prior to the commencement of works and periodically during operation.

During the works (if necessary) the decontamination of the following is to be provided for:

- open skin of the staff;
- temporary structures on the construction site;
- construction and transport equipment;
- small equipment and tools;
- PPE and work footwear.

The necessity and frequency of decontamination of the facilities mentioned above depend on the results of radiation monitoring.

Selection and equipment of the station for decontamination of the construction and transport equipment, as well as small equipment and tools, are carried out by the Contractor.

Washing the open skin of the staff will be carried out in the wash basins, located in the premises of temporary sanitary inspection station.

Washing of work shoes in trays with decontamination solution will be carried out in places where they are installed.

Measures For The Prevention Of Potential Radiation Accidents And Minimizing Their Consequences During Construction Of The CSFSF

The most important measures for the prevention of potential radiation accidents and minimization of their effects to be taken during preparation of the CSFSF construction site are as follows:

- dust suppression during performance of the works related to high dusting — hauling cut trees, uprooting stumps, other earthworks;
- fire prevention;
- prevention of failure of radiation monitoring means;
- prevention of failure of personal protective equipment (PPE);
- prevention of human errors.

Minimization Of Dusting During Performance Of Earthworks

Intense dusting is expected in the performance of works on preparation of the construction site — hauling cut trees, grubbing of stumps and planning of the surfaces.

Measures to prevent this event are:

- dust control before and during the works that can cause substantial dust rise from the surface of the ground;

- monitoring of correct and consistent implementation of technological operations;
- execution of works in the most favorable time in terms of season (spring, autumn) and weather conditions (absence of strong winds, moderate rainfall, high soil moisture, etc.);
- issuing work permits to certified and qualified staff, instruction before works, in particular, on radiation and other conditions of work, most dangerous places, etc.;
- providing for temporary (mobile) station for the monitoring of the volume activity of air on the border of the CSFSF construction site during hauling cut trees, grubbing of stumps, planning of the surfaces, and other earthworks.

Fire Prevention

Most fire hazardous works on the preparation of the CSFSF construction site are deforestation and stubbing of stumps, because there is a probability of forest fires and fires of the forest bed leading to significant additional radiation exposure to personnel and the environment.

The most effective interventions for prevention of fire when working on the preparation of the CSFSF construction site are as follows:

- exclusion techniques using fire works;
- working during the seasons of low fire risk (if possible);
- timely cleaning of the site from forest residues (after logging) and uprooted stumps;
- ensuring reliability, operability, compliance with the rules of operation of technical equipment, failure of which may cause ignition;
- strict implementation of the fire safety and electrical safety regulations by the staff;
- providing staff with primary fire extinguishing means (fire racks);
- setting up of fire-protection mineralized belts around around the construction site and temporary structures of the Contractor;
- providing for reliable communication among the staff that monitors the safety of works and is directly involved in the works;
- issue of work permits only to qualified and certified personnel, instruction before works, relevant training to extinguish local fires.

During construction works, the fire may occur in the presence of combustible materials in the WA and the possibility of fire, failure of equipment or human error, as well as in case of violation of the fire safety requirements.

The most effective measures to prevent possible fires are as follows:

- minimizing the volume of hot works;
- preparation of WAs to eliminate (reduce) the fire risk, in particular exclusion of combustible materials, their timely removal;
- monitoring of correct and consistent implementation of technological operations;
- issue of work permits only to qualified and certified personnel, instruction before works.

Prevention Of Failure Of Radiation Monitoring Means

Measures to prevent this event are:

- preparation and implementation of the rules of radiation monitoring to ensure sufficient control of potential emergency situations and accidents;
- provision with serviceable, reliable technical means of radiation monitoring (in particular, regular operability checks before works) and compliance with the rules of their operation;
- provision of the technical means of radiation monitoring with reliable power supply;
- radiation monitoring using certified and qualified personnel in compliance with the rules of radiation control.

Prevention Of Failure Of Personal Protective Equipment (PPE)

Measures to prevent this event are:

- providing the staff with additional PPE;
- compliance with the rules of use of additional personal protective equipment, in particular, in accordance with the terms and conditions of works, for which the PPE is intended;
- enforcement of monitoring of the integrity and serviceability of additional PPE;
- monitoring of contamination of basic and additional personal protective equipment;
- issue of work permits only to qualified and certified personnel, instruction before works, proper training to use the PPE.

Prevention Of Human Errors

Measures to prevent this event are:

- training of the staff to perform certain works;
- preparation for works and ensuring safety conditions in the workplaces;
- providing for reliable communication among the staff that monitors the safety of works and is directly involved in the works;
- monitoring of correct and consistent implementation of technological operations;
- creating the conditions for mandatory compliance with the rules of radiation, fire and industrial safety of the personnel;
- provision of radiation monitoring in the work areas and at the borders of zones;
- provision of personnel with reliable PPE according to the conditions of works;
- issue of work permits only to qualified and certified personnel, instruction before works, proper training.

The implementation of the above measures is expected to ensure acceptable levels of radiation safety.

10.7.1.4 Accidents During Construction

All original events during construction associated with falling of cargo or equipment failure do not lead to the exposure of personnel to radiation. As regards the possible external source of accidents on the construction site, the only critical event that can lead to significant radiation exposure to the CSFSF construction staff is forest fire in the early stages of preparatory works (prior to removal of vegetation).

This is due to the fact that the major part of construction and installation works will be carried out on an already treated area, so significant radiation exposure to personnel in such accidents as falling of cargo, cranes, etc. is not expected.

Fires are quite common in the Chernobyl exclusion zone. According to "Chernobylles" (Forestry) [153], 60-100 fires are registered annually, the vast majority of which occur in the areas not covered by forests (deposits). Given that the site preparation for the construction of CSFSF will include a set of activities to remove the stands on the construction site and building of access roads, the risk of fire and wood litter burning during such activities is quite high.

The fires in such conditions are of creeping type, when the litter, grass and shrub burns. In the process of development of such fires, the radionuclides emitted with smoke and soot and deposited on the wood and litter, will be distributed in the atmosphere leading to additional contamination of soil and increase of the concentration of radionuclides in the surface air layer. This process results in concentration of radionuclides in the ash litter and the release of radioactive aerosols into the air.

The initial data on fractional composition and biomass stock of forest vegetation on the CSFSF construction site are based on the experimental data presented in Tables 10.38 and 10.39.

Table 10.38 — **Fractional Composition Of Biomass Of Forest Stands On The CSFSF Construction Site**

Phytocenosis Component	Trunk		Branches	Leaves, Needl	Leaves Bed	
	Wood	Bark			AoL	AoF+AoH
Phytomass Stock, t/ha	111	22	23	4	7	11

Table 10.39 shows the fractional composition and biomass stock in the 30-40 year old forest stands, growing on the territory of the CSFSF construction site (in tonnes of absolutely dry substance per 1 hectare) [154].

The values of specific activity, in terms of ^{137}Cs, of the components of forest phytocenosis have been identified on the basis of the transition coefficient presented in [155].

Table 10.12 shows the content of ^{137}Cs in the components of the Scotch pine’s biomass (Bq/kg) at the contamination density of soil (230 kBq/m^2), taken into account in the assessment on the CSFSF construction personnel exposure.

Table 10.39 — **Accumulation Of ^{137}Cs In The Components Of Pine Phytocenosis, Bq/kg**

Trunk		Branches	Leaves, Needl	Leaves Bed	
Wood	Bark			AoL	AoF+AoH
56	111	223	270	170	21800

The calculations use the data on the litter contamination density set out in [156] based on the results of field experiments. In [156], it was found that creeping fires in the 30-40 year old pine phytocenoses burn the upper (AoL) and enzymatic (AoF) layers of litter. The humus layer (AoH) of the litter (which contains the bulk supply of radionuclides deposited in the litter) does not burn in creeping fires, and hence the radionuclides that have been deposited in it are not involved in the processes of the secondary transfer.

Numerous observations of the flow of creeping fire show that, after the initial phase, during which the fire area grows spontaneously, there comes the state of dynamic equilibrium, where the area is preserved in time: instead of burnt forest areas, there appear new plots of equivalent size [157].

The estimates show that the greatest danger is fire, which may occur during the construction in the northern part of the site with surface contamination values of about 160 kBq/m ^{2} ^{137}Cs, 40 kBq/m^2 ^{90}Sr and 4 kBq/m^2 α-active TUE.

The propagation velocity of surface fire front in the direction of wind may be from 0.5 to 3 m/min (the propagation velocity in the opposite direction is 6-10 times lower). At the average wind speed in the region (3.3 m/s at 10 m), the propagation velocity of creeping fire will be about 0.7 m/min. It is conservatively assumed that the velocity of propagation of fire is 1 m/min, the wind direction — in the direction of Chernobyl, and the point of fire — on the track axis.

In this case, the 4-hour fire will burn the total area of about 72 thousand m^2, which will lead to the total emission of about 10.8×10^8 Bq of ^{137}Cs, 2.9x10^8 Bq of ^{90}Sr and 2.9x10^8 Bq of alpha-active TUE. Here the time, t, during which complete combustion of forest litter to the state of dynamic equilibrium occurs is about 1000 seconds [157], the area of intense burning — about 5 thousand m^2, the rate of release — about 3.8x10^6 Bq/s for ^{137}Cs, 2.0x10^6 Bq/s for ^{90}Sr and 4.0x10^4 Bq/s for alpha-active TUE.

The modeling of radionuclide transfer process during creeping fire was based on a modified Gaussian model [158]. The impurity plume rise was calculated according to [160] with regard for the ultimate fire area [159] and the flame radius [161].

The calculations showed that the highest surface contamination will be observed at the distance of about 4000 meters from the site of fire and will amount to 4 Bq/m^2 for ^{137}Cs, 0.9 Bq/m^2 for ^{90}Sr, and 0.1 Bq/m^2 for alpha-emitting TUE.

The maximum volume activity of ^{137}Cs radionuclides in the air will be observed at the distances of ~4-5 km from the site of fire, and will not exceed 0.04 Bq/m^3. The maximum volume activity of ^{90}Sr in the air will not exceed 0.008 Bq/m^3, and the maximum value of volumetric activity of alpha-emitting TUE will not exceed 0.01 Bq/m^3.

The individual effective dose for the personnel at the distance of maximum surface concentration (approximately 4000 m) will be from 5 to 35 uSv, depending on the weather conditions, which does not exceed the dose limits established in NRBU-97.

It should be noted that the additional surface contamination and individual effective dose for the staff calculated using this method are conservative. The forest fire alert and suppression systems currently available in the Chernobyl exclusion zone can reduce the damage arising from forest fires.

The estimates show that the localization time for the forest fire under consideration (detection, departure of fire brigades, deployment, start extinguishing and localization of fire in the area where combustion occurs) is about 30 minutes. During this time, burn about 10% of forest plantations in the CSFSF area may burn. In addition, this approach assumes that the staff who will carry out the construction of CSFSF, will be in the zone of radioactive aerosols throughout the time of fire (about 4 hours). During the development of the construction project, it is planned to elaborate on the measures to evacuate the personnel in case of accidents during the construction.

It should be borne in mind that the fires in the exclusion zone may not be related to the CSFSF construction as well. To reduce or eliminate the risk of fire the measures to ensure fire safety were proposed.

10.7.2 Radiation Safety During CSFSF Operation

Radiation safety during operation of the CSFSF will be ensured, if the radiation impact on the personnel, population and environment is kept within normal operating conditions of the CSFSF, in case of violation of normal operating conditions and during design basis accidents that do not result in exceeding the established dose limits of radiation for workers and the public, the standards for emissions, discharges, content of radioactive substances in the environment, and will be limited during beyond design basis accidents.

10.7.2.1 Radiation Situation In The Territory And In The Premises Of CSFSF

The radiation situation in the territory and in the premises of CSFSF is determined by the factors that can be divided into two groups:

- the factors not associated with the CSFSF operation;
- the factors caused by the operation of CSFSF.

The main factor not related to the CSFSF operation, but forming the radiation situation is the ionizing radiation from the surface contamination of the territory as a result of the accident at the Unit 4 of the Chernobyl Power Plant in 1986. The value of the background radiation during operation of CSFSF will depend on the effectiveness of decontamination activities (removal of the surface layer of soil) carried out during the construction phase. The expected radiation contribution to the total dose after construction and installation works is significantly less than today.

The main sources of radiation in the territory and in the premises of CSFSF are the factors caused by the operation of CSFSF, namely MPC SFA during cargo transfer from HI-STAR to HI-STORM, and the HI-STARs and the HI-STORMs, loaded with MPCs with SFAs.

The CSFSF site, in terms of radiation hazard, is subdivided into the following areas:

- high-security zone — the territory, buildings and separate premises where the radiation exposure of personnel is determined by both the accidental pollution and the factors caused by the operation of CSFSF;
- free regime zone — the territory, buildings and separate premises where the radiation exposure of personnel is determined only by the accidental pollution, and where the sources of ionizing radiation, caused by the operation of CSFSF, are not handled;

The ionizing radiation sources, caused by the operation of CSFSF include:

- MPCs with SFA placed in the HI-STAR cask;
- MPCs with SFA in CTD during transfer from HI-STAR to HI-STORM;
- MPCs with SFA placed in the HI-STORM;
- equipment and filters of the exhaust ventilation system;

- RW casks;
- radioactively contaminated surfaces of equipment and facilities;
- radioactively contaminated PPE, kept in the sanitary inspection station;
- radioactively contaminated additional PPE.

At the specified division of the CSFSF territory into zones depending on the possible radiation exposure of personnel, the high-security zone comprises as follows:

- reception building premises listed in Table 10.40;
- storage area for HI-STORM casks;
- Automated Radiation Monitoring System station at the entrance to the casks storage facility;
- internal railway tracks and track №6 for holding HI-STAR cask cars with SFA.

The rest of the territory, buildings and separate premises of the CSFSF belong to the free regime zone.

Table 10.40 — **Reception Building Premises Within The High Security Zone**

Room No.	**Room Name**
	Mark 0.000
114	Central Room (transport-technological operations)
104	Machine repair shop
105	Room for cleaning and decontamination of machinery
106	Decontamination chemicals storage facility
107	Radiochemical laboratory
108	Vestibule
109	Floor drain tanks room
110	Monitoring tank room
111	Special sewage pumps room
112	Corridor
113	Staircase
115	PPE room
119	Lavatory
120	Cargo elevator well
123	Service room
124	Lobby
125	Tools storage facility
	Mark 4.200
222	KRB room
223	Wiping room
224	Shower room
225	Male locker room for overalls (sanitary inspection station)
226	Lavatory
227	Dirty overalls room
231	KRB room
232	Wiping room
233	Shower room
234	Female locker room for overalls (sanitary inspection station)
235	Lavatory
236	Dirty overalls room

Room No.	Roon Name
238	Corridor
239	KRB with washroom
240	Room for shift dosimetrist
241	Dirty overalls room
242	PPE room
	Marks 7.800, 11.000
402	Exhaust ventilation room
405	Corridor

Detailed description of the zoning of the territory and premises of CSFSF is supplied in Part 1 “Architectural-Construction Solutions. Architectural Solutions”, Volume 4.

10.7.2.2 Characteristics Of IRS

SFA are delivered to the CSFSF in sealed multipurpose casks — MPC. The main sources of ionizing radiation source in MPC is SFA. The CSFSF is expected to keep the SNF VVER-1000 and VVER-440 units.

Company Holtec International calculated [140, 142] the radiation protection of HI-STORM 190 and HI-STAR 190 spent nuclear fuel storage and transportation systems, the doses of MPC for CSFSF under normal, violations of normal operation and design base accidents.

The analysis of biological protection can be divided into two parts. The first part is the calculation of the radiation characteristics of spent nuclear fuel with the corresponding values of burnout and holding time. The second part is modeling of penetration of particles through the biological protection to assess the dose values at various points.

The calculations of radiation protection [140, 142] were made using the following computer codes:

- SAS2H/ORIGEN-S (software modules of SCALE 4.4) — for the calculation of accumulation and decay of nuclides in the fuel assembly, the radiation characteristics of spent nuclear fuel and residual energy after discharge from the reactor assembly.
- MCNP5 version 1.40 — general purpose code based on the Monte Carlo method, used to calculate the transfer of individual particles (neutrons, photons, electrons) and the joint transfer of particles (neutron/photon/electron).

MPC is a sealed cask with two sealing barriers. Tightness of the MPC is provided by design and quality of workmanship as in [139]. Based on this, the internal exposure doses for personnel in the course of handling of spent nuclear fuel under normal operating conditions of the CSFSF are absent.

The doses of external radiation during handling of SNF on the CSFSF are determined by the gamma and neutron radiation from the spent nuclear fuel.

The gamma radiation of the spent nuclear fuel comes from three separate sources. The first is the sources of gamma radiation in the active (fuel) zone of SFA resulting from decay of fission products and actinides. The structure of this source of radiation consists of 163 main radionuclides — fission products and radionuclides — actinides present in the spent fuel. The second source is the radionuclides of ^{60}Co in the steel structural materials of the fuel assembly, which are located above and below the fuel portion of the fuel assembly. The main source of gamma radiation in the structural materials of the VVER SFA is ^{60}Co.

Inclusions of ^{59}Co contained in the stainless steel of the head and shank of the FA, under neutron radiation, are activated into radioactive ^{60}Co with half life of 5.27 years. In order to calculate the content of inclusions of ^{59}Co in the steel structural elements, it is conservatively assumed at four times the content in the stainless steel. The third is the gamma radiation as a result of (n, γ) reactions.

The neutron radiation includes spontaneous fission and (α,n) reactions of the actinides, such as ^{238}Pu, ^{242}Cm and ^{244}Cm.

[140] contains the analysis of the characteristics of VVER-1000 and VVER-440 fuel assemblies, and the selection of maximum values of the parameters in terms of radiation. In order to select the maximum (in terms of radiation characteristics) parameters, different characteristics of SFA were analyzed: UO_2 weight, diameter of the tablet, enrichment tolerances, burning, exposure time, etc., resulting in a defined set of characteristics that lead to the maximum dose values.

When calculating the radiation characteristics, the following key assumptions were considered:

- A single full fuel cycle exposure until required burnout was assumed.
- The content of ^{59}Co inclusions in the steel elements of the FA was assumed at 1 g/kg. This assumption is conservative, since the content of ^{59}Co in the steel grades used for the core structures is 0.25 g/kg.
- The temperature of the fuel cladding for VVER-1000 and VVER-440 was assumed at 607.8 K.
- For VVER-440, the fuel portion length in the "hot" state was assumed at 2500 mm, for VVER-440, the fuel portion length in the "hot" state was assumed at 3550 mm.

The calculations of maximum values of initial fuel enrichment using MCNP5 code: fuel enriched to 4.34% ^{235}U for VVER-440 with maximum depth of burn of 55000 MW*d/t(U) and FA enriched to 4.6% of ^{235}U for VVER-1000 with the maximum depth of burn of 58000 MW*d/t(U) [140].

Tables 10.41-10.44 show the parameters of MPC, HI-STAR 190 and HI-STORM 190 used in the calculations of biosecurity [140, 142].

Table 10.41 — **Features Of MPC-31 For VVER-1000 Spent Fuel Assemblies [140]**

Component and Parameter	Value
Fuel basket	
Number of cells, pcs	31
The total height of the basket, mm	4400
Inner cell diameter, mm	243.6
Hermetic casing	
Inner diameter, mm	1835
Outer diameter, mm	1924
Height of the internal cavity, mm	4618
Overall height, mm	5047

Table 10.42 — **Features Of MPC-85 For VVER-440 Spent Fuel Assemblies [140]**

Component and Parameter	Value
Fuel basket	
Number of cells, pcs	85
The total height of the basket, mm	3185
Inner cell diameter, mm	155
Hermetic casing	
Inner cavity diameter, mm	1875

Component and Parameter	Value
Outer cavity diameter, mm	1924
Height of the internal cavity, mm	3278
Overall height, mm	5074

Table 10.43 — **Features Of HI-STAR 190 Cask [140]**

Component and Parameter	Value, mm
Overall height	5657.8
Outer diameter	2708
Inner cavity diameter	1933.6
Depth of cavity	5057
Cask body	
Inner diameter of the neutron shielding	2365.4
Outer diameter of the neutron shielding	2683
Journals	
Diameter	266.7
Cap	
Total thickness	200
Outer diameter	2190.8
Damping device	
Outer diameter of the shock ring	3251

Table 10.44 — **Features Of HI-STORM 190 Cask [140]**

Component and Parameter	Value, mm
Overall height	5403.12
Outer diameter (at bottom)	3556
Cask body	
Height of the inner and outer shells	5097
Inner diameter of the inner shell	2057.4
Outer diameter of the inner shell	2095.6
Inner diameter of the outer shell	3492.6
Outer diameter of the outer shell	3530.8
Bottom and top plate	
Bottom diameter	3556
Thickness of the upper plate	25.4
Bottom thickness	76.2
Cap	
Total thickness	273.1
Outer diameter	3178.2

The radiation characteristics, assumed while calculating the doses [140, 142], are shown in Tables 10.45, 10.46 and 10.47.

Table 10.48 contains the data [140] on the isotopic composition of the fuel for the isotopes, whose contribution to the total activity is at least 0.1%.

Table 10.45 — **Range Of Gamma Radiation On The SFA [140]**

Min. energy	Max. energy	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 6 years		VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 7 years		VVER-440 SFA, burning of 53,500 MW*d/t(U), ageing — 5 years	
(MeV)	(MeV)	(MeV/s)	(photons/s)	(MeV/s)	(photons/s)	(MeV/s)	(photons/s)
4.50E-01	7.00E-01	2.21E+15	3.85E+15	1.98E+15	3.44E+15	5.94E+14	1.03E+15
7.00E-01	1.00E+00	6.85E+14	8.06E+14	5.07E+14	5.96E+14	1.83E+14	2.15E+14
1.00E+00	1.50E+00	2.32E+14	1.86E+14	1.96E+14	1.57E+14	4.98E+13	3.98E+13
1.50E+00	2.00E+00	1.25E+13	7.15E+12	1.04E+13	5.92E+12	3.35E+12	1.91E+12
2.00E+00	2.50E+00	3.00E+12	1.33E+12	1.34E+12	5.96E+11	7.15E+11	3.18E+11
2.50E+00	3.00E+00	1.61E+11	5.85E+10	8.17E+10	2.97E+10	3.93E+10	1.43E+10
Total		3.14E+15	4.85E+15	2.69E+15	4.20E+15	8.30E+14	1.29E+15

Table 10.46 — **Range Of Neutron Radiation On The SFA [140]**

Min. energy	Max. energy	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 6 years	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 7 years	VVER-440 SFA, burning of 53,500 MW*d/t(U), ageing — 5 years
(MeV)	(MeV)	(neutron/s)	(neutron/s)	(neutron/s)
1.0E-01	4.0E-01	5.25E+07	5.06E+07	1.55E+07
4.0E-01	9.0E-01	1.14E+08	1.10E+08	3.38E+07
9.0E-01	1.4	1.14E+08	1.10E+08	3.37E+07
1.4	1.85	9.12E+07	8.78E+07	2.69E+07
1.85	3.0	1.70E+08	1.64E+08	5.01E+07
3.0	6.43	1.54E+08	1.49E+08	4.55E+07
6.43	20.0	1.47E+07	1.42E+07	4.34E+06
Total	6.23E+08	7.11E+08	6.85E+08	2.10E+08

Table 10.47 - **Activity Of Construction Materials Of The SFA [140]**

Exclusion	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 6 years	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 7 years	VVER-440 SFA, burning of 53,500 MW*d/t(U), ageing — 5 years
Unit	(photons/s)	(photons/s)	(photons/s)
FA head	1.82E+13	1.60E+13	5.48E+12
Plenum	2.79E+12	2.44E+12	-
Fuel portion	1.42E+14	1.24E+14	-
FA shank	2.55E+13	2.24E+13	1.05E+13

Table 10.48 - **Isotopic Composition Of Fuel (g) In The SFA [140]**

Isotope	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 6 years	VVER-1000 SFA, burning of 55,000 MW*d/t(U), ageing — 7 years	VVER-440 SFA, burning of 53,500 MW*d/t(U), ageing — 6 years
^{241}Pu	9.13E+02	8.7E+02	2.44E+02
^{137}Cs	8.51E+02	8.31E+02	2.31E+02
^{137m}Ba	1.30E-04	1.27E-04	3.52E-05
^{90}Sr	3.40E+02	3.31E+02	9.22E+01
^{90}Y	8.83E-02	8.61E-02	2.40E-02
^{134}Cs	1.64E+01	1.17E+01	4.36E+00
^{147}Pm	2.11E+01	1.62E+01	5.39E+00
^{106}Ru	2.15E+00	1.09E+00	5.23E-01
^{144}Ce	1.04E+00	4.26E-01	2.46E-01
^{144}Pr	4.40E-05	1.81E-05	1.040E-05
^{244}Cm	6.31E+01	6.07E+01	1.82E+01
^{85}Kr	1.23E+01	1.15E+01	3.30E+00
^{154}Eu	1.77E+01	1.64E+01	4.88E+00
^{238}Pu	2.53E+02	2.51E+02	7.41E+01
^{125}Sb	1.50E+00	1.17E+00	3.47E-01
^{241}Am	3.51E+02	3.93E+02	9.56E+01

The maximum dose rates, obtained in [140], which were used in calculation of the personnel radiation exposure, are set out in Tables 10.49-10.50.

Table 10.49 shows the results of calculation of the maximum dose rates [140] for the MPC-31, from the center of the surface of the MPC-31 top cap. Table 10.50 shows the dose rates for MPC-85 with the same geometry [140].

Table 10.49 — **Maximum Dose Rate As A Function Of Distance From The Center Of The MPC-31 Cap [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Total (mSv/h)
0	0.585	4.705	0.354	0.006	5.650
1	0.197	1.280	0.048	0.002	1.527
2	0.103	0.675	0.075	0.001	0.854

Table 10.50 — **Maximum Dose Rate As A Function Of Distance From The Center Of The MPC-85 Cap [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Total (mSv/h)
0	1.257	3.412	2.313	0.010	6.991
1	0.447	0.734	1.150	0.004	2.334
2	0.211	0.501	0.570	0.002	1.284

Table 10.51, according to [140], shows the maximum dose rates of HI-STAR 190 with MPC-31 under normal operation and accident conditions. Falling and fire were assumed as two possible events leading to deterioration of the properties of biological protection of the HI-STAR 190 casks. The borderline case was analyzed for both of these situations using the configuration in which the cask has no neutron protection — material Holtite.

Table 10.52 shows the maximum dose rates of HI-STAR 190 with MPC-85 under normal operation as described for HI-STAR 190 with MPC-31 above.

Table 10.51 — **Maximum Dose Rates On The Surface Of HI-STAR 190 With MPC-31 [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Subtotal (mSv/h)
Normal Operation					
0 (at the surface)	1.027	0.067	0.050	0.015	1.159
Emergency Conditions					
1	5.985	0.030	0.071	0.016	6.102

Table 10.52 — **Maximum Dose Rates On The Surface Of HI-STAR 190 With MPC-85 [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Subtotal (mSv/h)
Normal Operation					
0 (at the surface)	0.796	<0.0001	0.038	0.081	0.914
Emergency Conditions					
1	6.318	0.026	0.077	0.014	6.435

Table 10.53 shows the maximum dose rates of HI-STORM 190 with MPC-31 (lateral surface) according to [140], and Table 10.54 shows the maximum dose rates of HI-STORM 190 with MPC-85. The dose rates stated in Tables 10.53 and 10.54 are for normal operation.

Due to highly reliable design of the storage unit in HI-STORM 190, considered in [140] in accordance with [39], the hypothetical accident (flood, fire, earthquake, hit by flying object) will not affect the biological protection performance of the cask. Accidents involving rollover of the storage unit of HI-STORM 190 are excluded by the design requirements. In some emergency situations (blockage of ventilation ducts, flooding, debris accumulation), the values of the dose rate of the cask will be lower than under normal conditions. Accordingly, the normal conditions of storage with the design fuel inside are the boundary conditions that also cover contingencies and emergency storage conditions.

Table 10.53 **— Maximum Dose Rate Of The Lateral Surface Of HI-STORM 190 Loaded With VVER-1000 Fuel (MPC-31) [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Subtotal (mSv/h)
0 (at the surface)	0.024	0.115	0.264	0.028	0.429
1	0.010	0.052	0.135	0.013	0.211
2	0.006	0.038	0.084	0.007	0.134

Table 10.54 **- Maximum Dose Rate Of The Lateral Surface HI-STORM 190, When Loading VVER-440 Fuel (MPC-85) [140]**

Distance, m	Neutron radiation (mSv/h)	^{60}Co (mSv/h)	SNF gamma (mSv/h)	N-gamma (mSv/h)	Subtotal (mSv/h)
0 (at the surface)	0.027	0.001	0.427	0.030	0.485
1	0.010	0.023	0.199	0.012	0.243
2	0.005	0.027	0.107	0.006	0.145

10.7.3 Estimated Doses Under Normal Operation

The doses received by the personnel during normal operation will be determined mainly by:

- handling of HI-STAR and HI-STORM casks in the central transfer room;
- maintenance of the storage facility.

This section provides enlarged estimate of the dose rates affecting the CSFSF personnel while performing works, as provided by Holtec. The detailed evaluation of radiation dose rates should be given in the PSAR.

10.7.3.1 Evaluation Of The Dose Rates During Handing Of MPCs In The CSFSF

The received dose rate estimate depends on the following initial conditions:

- the team that conducts works in the central room of the building and the reception team that performs works on power units is the same team;
- according to the Customer's data, the maximum expected number of HI-STAR casks with spent nuclear fuel received by the CSFSF is 16 pieces a year;
- the dose rates for the vehicle drivers are not taken into account, as drivers perform on the works related to transportation to the CSFSF;
- the specific location of personnel is not taken into account, it is believed that the personnel involved in the operation is affected by the same dose rate;
- in order to perform the works according to the data by Holtec’s technology developers, the team should consist of five (operators 1-5), who can perform all the necessary operations;
- it is assumed that 50% of the allowable individual dose rate is received by the personnel while loading at the reactor units, another 50% — during transfer at the CSFSF.

The estimation of dose rates for the personnel while handling the spent fuel in the reception building is presented in Table 10.55.

Table 10.55 — **Estimated Dose Rates For The Personnel In Case Of Transfer Of MPCs At The CSFSF**

Works	Operations Duration, h	Average Dose Rate, mSv/h	Maximum Annual Dose Rate For Operation (16 Casks Per
Reception of the transporter rail car with the HI STAR transport cask, loaded with MPC with SFA			
- removal of the personnel barrier (protective cover);	0.3	1.16	5.57

Works	Operations Duration, h	Average Dose Rate, mSv/h	Maximum Annual Dose Rate For Operation (16 Casks Per Year), mSv/year
- removal of fixing ties from the HI-STAR;	0.17	1.16	3.16
- removal of the dampers.	0.17	0.31	0.84
SUBTOTAL			***9.57***
Preparation of HI-STAR for transfer of the MPC to the HI-STORM			
- tipping of the HI-STAR cask from the horizontal to vertical position and unloading of the HI-STAR cask from the rail car to a special work platform;	0.17	1.16	3.16
- sampling of the gas from the annular gap of the HI-STAR;	0.1	0.31	0.50
- HI-STAR lid removal;	0.4	0.31	1.98
- installation of the lifting device (accessory) to the MPC;	0.3	5.65	27.12
- alignment of the CTD and the HI-STAR.	0.04	0.85	0.54
SUBTOTAL			***33.30***
Transfer of the MPC to the HI-STORM			
- removal of spindles (stops), CTD;	0.04	0.85	0.54
- installing stops, CTD;	0.04	0.43	0.28
- alignment of the MPC lifting yoke;	0.04	0.43	0.28
- CTD stops extension;	0.4	0.43	2.75
- disconnecting the MPC lifting device.	0.2	5.65	18.08
SUBTOTAL			***21.93***
Transfer of the HI-STORM cask from the reception and handling building to the storage area by a special vehicle			
- installation of the cap on the HI-STORM cask;	0.33	0.4	2.11
- attaching VCT lifting lugs to the HI-STORM;	0.08	0.43	0.55
- fixing of the HI-STORM to the VCT using hydraulically tensioned hold-down belts;	0.08	0.43	0.55
- transfer of the HI STORM to the storage site;	0.5	0.21	1.68
- disconnection of HI-STORM from the VCT on the permanent	0.17	1.08	2.94

Works	Operations Duration, h	Average Dose Rate, mSv/h	Maximum Annual Dose Rate For Operation (16 Casks Per Year), mSv/year
storage site;			
oval of the lid fasteners from the HI-STORM cask;	0.08	1.08	1.39
- checking the temperature control system, replacement of the IAEA seals.	0.08	1.08	1.39
SUBTOTAL			***10.61***
annual dose, mSv/year			**75.4**

Given that the team spends most of the year at the CSFSF located in the exclusion zone, the assessment of the individual dose rates is based on the reference level of external exposure in the exclusion zone, i.e. 11 mSv/year.

Thus, for the team performing the operations set out in Table 10.28, the individual dose rate limit is estimated at 5.5 mSv/year.

In order to prevent the exceedance of the individual annual dose, the number of staff performing the transfer at the power units and at the CSFSF should be: 75.4/5.5=13.7 or 14 people. Thus, it is proposed to provide for three teams of 5 people.

10.7.3.2 Evaluation Of Doses During Maintenance Of The Cask Storage Area

The received dose rate estimate depends on the following initial conditions:

- the maintenance of storage site is performed by the following staff not involved in other radiation-hazardous operations:
  - the lineman performs inspection, physical activities, drives motor vehicles, cleans the territory;
  - the control and instrumentation technician services the temperature control system;
  - the electrician services the electrical systems.
- the dose assessments is performed for the most loaded storage site — the design capacity is 458 casks;
- when working with a HI-STORM cask, a set of works (checking ventilation ducts, external examination) is performed;
- the vehicular traffic speed on the site is limited — no more than 5 km/h;
- it is assumed that as a result of daily work around by car, in case of blockage of the duct or presence of debris near the duct, the inspector will call for additional staff to such a cask. Therefore, the dose rate during cleaning of the ventilation ducts are not considered;
- checking and calibration of the temperature control system — no more than once in three years;
- checking the grounding system — no more than once a year;
- removal of garbage, snow, leaves — no more than once a month;

- remote monitoring of the MPC state using video cameras is performed via upper air ducts during inspection of the upper air ducts — not more than once every four years;
- external inspection of the site is carried out daily by car;
- the assessing of the doses rate does not provide for the maintenance of the radiation monitoring system sensors, as they are located in the places not affected by the casks in the storage.

The estimation of dose rates for the personnel while handling the spent fuel in the reception building is presented in Table 10.56.

The following special equipment is planned for maintenance operations:

- mobile cradle for servicing output air ducts and control devices located at a height;
- snow-fighting vehicle.

Table 10.56 — **Assessment Of Doses During Maintenance Of The Cask Storage Area**

Works	**Operations Duration, h**	**Average Dose Rate, mSv/h**	**Number Of Operations Per Year**	**Maximum Annual Dose For The Operation, mSv/year**
Inspector				
Visual inspection	0.5	0.68	365	124.10
Removal of snow, garbage, leaves	1.5	0.68	12	12.24
Inspection of the outer surface of the HI-STORM and MPC	0.33	0.68	114.5	25.69
Driver for the control and instrumentation technician	0.5	0.68	153	51.91
SUBTOTAL				***213.94***
Control and instrumentation operator				
Checking and calibration of the temperature control system:				
on the HI-STORM cover	0.33	0.161	153	8.11
on the HI-STORM lateral surface	0.17	0.68	153	17.65
SUBTOTAL				***25.76***
Electrician				
Grounding check	8	0.68	1	5.44
SUBTOTAL				***5.44***

In order to meet the criterion of individual dose rate of 11 mSv/year established for the maintenance of the storage site, the following personnel is required:

- Inspector: 213.94/11=19.44 or 20 people;
- Control and instrumentation technicians: 25.76/11=2.34 or 3 people;
- Electrician: 5.44/11=0.5 or 1 person.

10.7.3.3 Measures To Ensure Radiation Safety Under Normal Operation Of The CSFSF

Radiation safety of the operating and maintenance personnel is ensured by a set of organizational, technical and radiation-hygienic arrangements.

Organizational Arrangements

Before the beginning of operation and periodically during operation, it is expected to conduct the following activities:

- preparation of workplaces;
- admission to the production of works;
- human resource training;
- monitoring and supervision;
- organization of health care.

Staff training is aimed at gaining knowledge in the field of radiation, general technical and fire safety regulations when working on the CSFSF, both in normal operation and in case of possible accidents, as well as the knowledge and practical skills in the technological processes of MPC handling during their transportation, preparation for storage and storage.

Staff training includes the study of regulatory and technical documentation on operation of the enterprise, the rules of conduct in the exclusion zone, as well as action during emergencies and accidents to the extent required by the job descriptions and assigned responsibilities. Upon completion of training, the staff will undergo testing of knowledge with the issue of certificates.

Staff training will be carried in accordance with the specially developed programs, which include the study of the following materials:

- The rules of conduct in the territory of the CSFSF, including:
  - the rights and duties of CSFSF staff;
  - the order of CSFSF site entrance and exit;
  - the procedure for obtaining and use of personal dosimeters;
  - the procedure for the passage through the radiation monitoring stations.
- The fundamentals of dosimetry, radiation hazardous of the CSFSF, the methods of protection against ionizing radiation, as well as the parameters of the radiation situation in places of works.
- The rules of use of personal protective equipment (PPE), including:
  - components of the basic set of personal protective equipment and respiratory protective equipment;
  - procedure for the use of PPE.
- Procedures for possible emergencies and accidents, including:
  - actions in the event of emergency;
  - escape routes in case of an accident;
  - first aid to the victim, etc.

Professional training is carried out according to the employee's specialization in the form of theoretical study of production schedules of works, assigned duties, and developing practical skill using simulator. After checking the knowledge gained as a result of theoretical training and work with simulators, the staff practices using empty MPCs to acquire practical skills in the production situation. Upon receipt of positive results, the employee is allowed to carry out certain manufacturing operations under the supervision of an experienced instructor with gradual extension of the scope of operations as experience is gained.

To improve the safety of works, additional targeted training is planned. The procedure for conducting targeted training of the staff is determined in accordance with the requirements of the regulatory documents.

Monitoring and supervision is carried out to improve the safety of work and to prevent violations of regulations in the performance of manufacturing operations that may lead to emergency situations and unnecessary overexposure of personnel.

Medical care is offered to the personnel by the medical station localed in he administrative building.

The organizational arrangements are set out in Section 8, “Occupational Safety”, of Volume 1.

Technical Measures

The main technological protection measures to ensure radiation safety under normal operating conditions are as follows:

- shielding;
- use of remotely controlled mechanism (described in detail in Volume “Technological Part. Spent Nuclear Fuel Handling”);
- decontamination (described in detail in Volume 3.2, “Technological Part. Waste Management During Operation”);
- special ventilation and special gas treatment (described in detail in Volume 7, “Heating, Ventilation, Air Conditioning”).

The radiation safety of the CSFSF is built on the principle of multi-barrier protection.

The MPC barrier is an obstacle to the mechanical spread of radioactive substances into the environment, which practically does not prevent the spread of ionizing radiation. The barriers that have the function of protection against radiation are cask handling unit for casks transfer, the HI-STAR cask — during transportation, the HI-STORM cask — during storage.

One of the main measures in radiation protection is shielding that reduces radiation exposure based on the ALARA principle to the level stipulated by the regulations.

The design is based on the differentiated approach to shielding with due regard for the following:

- the specifics of the technological process;
- the need for the presence of personnel during implementation of certain operations;
- the time spent by the personnel in various areas.

The ventilation of premises where the casks are processed is an additional dynamic barrier to the spread of radioactive substances into the environment.

Ventilation is arranged in such a way that the air from the dirty rooms does not get into the room where the staff stays permanently. The air removed from the technological premises is cleaned by aerosol filters prior to release into the surrounding air.

The performance of works during SNF processing with the use of remotely controlled mechanisms and video surveillance. If necessary, decontamination of facilities and equipment is also provided for.

Radiation-Hygienic Measures

The main planned radiation-hygienic measures during normal operation are as follows:

- establishment of the sanitary protection zone and the surveillance zone;
- assessment of exposure dose rates of personnel and the establishment of reference levels;
- introduction of sanitary and access control;
- zoning of premises and territories;
- use of PPE and RPE;
- radiation monitoring.

In accordance with the requirements of [39], the CSFSF is surrounded by a sanitary protection zone and a surveillance zone.

According to NRBU-97 [101], the sanitary protection zone is understood as an area around a radiation/nuclear facility where the human exposure level under normal operating conditions can exceed the quota of the dose limit for population (1 mSv/year). Individuals are prohibited from residing within the SPZ, while productive activities not related to the radiation/nuclear facility are restricted and radiation monitoring is exercised [101, 110].

Based on the criterion of non-exceeding the dose of 1 mSv/year under normal operation of the CSFSF, the SPZ boundary is set at a distance of 100 meters from the boundaries of the CSFSF production site (when the storage is completely filled with 459 HI-STORM casks).

In accordance with NRBU-97 [101], the surveillance zone is the territory, where there is possibility of radioactive discharge and emission from the CSFSF and where radiation monitoring is carried out.

The CSFSF project provides for the establishment of the surveillance zone at a distance of 600 m from the site boundaries.

Justification of the sizes of SPZ and SA is set out in EIA.

According to [112], all the personnel permanently working in the exclusion zone, regardless of the nature of the works, belong to the Category A staff pursuant to NRBU-97 [101]. With this in mind, taking into account the requirements of [110, 112], the draft project establishes the following reference levels (RL) of exposure of the CSFSF staff (effective dose rates):

- 11.0 mSv/year from external radiation;
- 3.0 mSv/year from internal radiation.

Sanitary and access control will be implemented at the CSFSF.

The sanitary and access control is necessary for physical protection and to prevent the transfer of radioactive contamination beyond the CSFSF site, PPE and skin contamination control, overalls changing and sanitary treatment of personnel, collection and dispatch of contaminated PPE for decontamination and disposal. Detailed description of sanitary and access control is provided in Section 8 of “Occupational Health”, Volume 1.

The territory, buildings and premises of the CSFSF, in terms of degree of radiation hazards, are divided into the following areas:

- high-security zone — the territory, buildings and separate premises where the radiation exposure of personnel is determined by both the accidental pollution and the factors caused by the operation of CSFSF;
- free regime zone — the territory, buildings and separate premises where the radiation exposure of personnel is determined only by the accidental pollution, and where the sources of ionizing radiation, caused by the operation of CSFSF, are not handled; More detailed zoning of the CSFSF is set out in paragraph 10.4.1.1.

During performance of works at the CSFSF, the staff, if necessary, will use PPE and RPE [110]. The use of PPE and RPE is detailed in Section 8.

In order to monitor the the radiation exposure of personnel, population and the environment under normal operating conditions of the CSFSF, violations of conditions of normal operation and design-basis accidents at the CSFSF, the radiation monitoring system (RMS) is planned. Its operation will provide the staff with the possibility to keep pollution levels and the radiation exposure dose rates of the workers and the public reasonably below the regulated limits.

Radiation Monitoring System (RMS) consists of the following subsystems:

- technological process radiation monitoring (PRC);
- radiation dosimetric monitoring (RDM);
- individual dosimetric monitoring (IDM);
- environmental radiation monitoring (ERM);
- radiation monitoring of spread of radioactive contamination. Depending on the

nature of the work, radiation monitoring includes:

- monitoring of the dose rates of ionizing radiation, beta and alpha flux density of particles in the workplace, industrial premises and the territory of the sanitary protection zone and the surveillance zone;
- monitoring of radioactive gases and aerosols in the production and administrative premises;
- monitoring of the level of contamination of production facilities, equipment surfaces, skin and clothing of the personnel;
- monitoring of release of radioactive substances into the atmosphere;
- monitoring of collection and handling of solid and liquid radioactive waste;
- vehicles contamination monitoring.

The CSFSF radiation monitoring systems is described in detail in Volume 6, “Monitoring And Control System”.

10.7.4 Radiation Safety In Case Of Accident

In accordance with the requirements of NP 306.2.105-2004 [39], a detailed analysis of accidents at the CSFSF is set out in PSAR.

Holtec International have analyzed accidents and presented the results in “Report On The Analysis Of Accidents”. Holtec International HI-2083899 [142] (a copy is supplied in Volume 1.2.2). The accident analysis report by Holtec International contains a list of initiating accidents that were determined on the basis of the requirements of NP 306.2.105-2004 [39], PNAE G-14-029-91 [69], and RD 306.8.02/2.067-2003 [134].

The Report HI-2083899 [142] deals with the following initiating events giving rise to the disturbance of regular operating conditions and design-basis accidents corresponding to the requirements of NP 306.2.105-2004 [39]:

- natural phenomena:
  - flooding;
  - tornadoes and objects carried by tornadoes;
  - earthquake;
  - extreme snowfall;
  - extreme increase in ambient temperature;
- technology-related external events:
  - fire or explosion at a neighboring facility (a passing vehicle);
  - blackout;
  - airplane fall on a HI-STORM cask;
- technology-related internal events:
  - fire;
  - flying objects generated by other accidents;
  - human error;
  - failures of fuel management and storage systems;
  - fall of objects;
  - clogging of HI-STORM vents;
  - rollover of the storage unit of HI-STORM;
  - accident during transportation;
  - MPC jamming during transfers.

A brief description of results of the probable accident and emergency situation development analysis based on the initiator events is provided hereinbelow in Table 10.57 on the basis of materials of HI-2083899 [142].

The report of the results of analysis of accidents HI-2083899 [142] shows that all the reviewed disturbances of regular operating conditions and design-basis accidents will not exceed safe operation limits and will not give rise to the discharge of radioactive substances into the environment.

Inv. No Signature, Date Repl. Inv. No

Amd. Nr.am Sheet Doc. No. Sig. Date

571402_201_001_PZ01_ред.2

Table 10.57 — **Analysis Of Emergencies And Accidents In Accordance With The Report [142]**

Initiator Event (IE)	IE Parameters	Reception Criteria Used for Analysis	Analysis Results
Design-basis natural IEs			
Earthquake	The spectra of seismic responses for the CSFSF site (corresponding to the spectra of ChNPP, received in the NAEC letter № 03-46/340 of March 12, 2015)	HI-STORM 190 cask should remain stable without tipping	Analysis of HI-STORM 190 stability and docking mechanism strength analysis confirmed that the acceptance criterion is amply met.
Tornadoes and objects carried by tornadoes	Tornado parameters: in accordance with the letter of NAEC No. 03-46/1440 of September 29, 2015, "Tornado parameters for the CSFSF area" Objects carried by tornado: - a 1800 kg car at a speed of 203 kph; - a 125 kg, D200 mm steel cylinder at a speed of 203 kph; - a 0.22 kg, D25 mm steel cylinder at a speed of 203 kph.	The cask should not trip. The collision with objects carried by a tornado must not result in the damage that will increase the exposure rate at the site boundary.	The analysis of the stability and the impact of flying objects confirmed that the simultaneous impact of an extreme wind and a flying object impact would not knock over a HI-STORM 190 cask and reduce efficiency of the containment shell for the MPC, and, accordingly, would not increase the exposure rate at the site boundary.
Extreme increase in ambient temperature	from –40 °C to +40 °C	The fuel element shell temperature must not exceed the maximum level. Fuel element temperatures must not exceed limits set for accident conditions.	The thermal analysis confirmed that the temperature behavior of a HI-STORM 190 cask filled with spent nuclear fuel from VVER reactors with the design-basis heat output in a MPC-31 or MPC-85 would ensure that all the design-basis temperature limits are met at extreme values of the ambient temperature.
Extreme snowfall	Snow load: 4.8 kPa (100 lbs per square foot). Complete clogging of vents	The container system must remain structurally integral. Fuel element temperatures must not exceed limits	The snow load considered is negligible in comparison with other loads under review; for this reason no additional strength

571402.201.001-PZ01

Size A4

Orig. Inv. No.	Signature, Date	Repl. Inv. No.

Initiator Event (IE)	IE Parameters	Reception Criteria Used for Analysis	Analysis Results
		set for accident conditions.	analysis for the snow load is called for. The thermal analysis of the HI-STORM 190 storage system in case of the clogging of vents demonstrated that temperature values would not exceed the allowed limit even in case of the conservative overstatement of the time needed for unclogging vents.
Flooding	Water level increase velocity: 4.57 meters per second (15 feet per second). Water level increase height: 109.9 m	The cask should not trip. The fuel element shell temperature must not exceed the maximum level.	The strength analysis and the stability analysis demonstrated that flooding would not knock over or displace a HI-STORM 190 cask. Flooding would not affect thermal properties of the system negatively. The heat abstraction will improve.
Design-basis technology related initiator events (external)			
Fire or explosion at a neighboring facility, passing of a vehicle with flammable or explosive cargo	A loaded HI-STORM 190 is moved to the CSFSF storage area by a VCT. An assessment of the impact of the ignition/explosion of combustible substances available in a VCT has been carried out	The fuel element shell temperature must not exceed the maximum level. Fuel element temperatures must not exceed limits set for accident conditions. The event must not result in a substantial increase in the exposure rate at the site boundary	The thermal analysis demonstrated that the fire would not affect the integrity of the containment shell of the MPC and the shell of a fuel element. The stability analysis confirmed that the explosion would not knock over a HI-STORM 190 cask.
Blackout	Suspended operation of electrically driven mechanisms, such as cranes; stopped process operations	The fuel element shell temperature must not exceed the maximum level.	A blackout would not result in the development of emergency conditions or

Initiator Event (IE)	IE Parameters	Reception Criteria Used for Analysis	Analysis Results
			design-basis accident. There would be no impact on the exposure rate at the site boundary; there is no hazard to human safety.
Airplane fall on a HI-STORM 190 cask	Airplane velocity, mass, angle of entry, and amount of fuel aboard	Preserved integrity of the containment shell of the MPC	The strength and thermal analysis for a fall of a 20-tonne airplane at an impact velocity of 215 meters per second demonstrated the lack of substantial damage to the cask and the preservation of its functional integrity.
Design-basis technology related initiator events (internal)			
Partial clogging of fresh air inlets	50% of the area of fresh air inlets are clogged	The fuel element shell temperature must not exceed the maximum level. Fuel element temperatures must not exceed limits set for accident conditions.	The thermal analysis confirmed the conformity with the temperature and pressure limits for deviations from normal conditions
Complete clogging of vents	100% clogging of vents with debris	The fuel element shell temperature must not exceed the maximum level. Fuel element temperatures must not exceed limits set for accident conditions.	The thermal analysis demonstrated that temperature values would not exceed the allowed limit even in case of the conservative overstatement of the time needed for unclogging vents (30 hours).
Fuel element rupture	Complete (100%) fuel element rupture	The fuel element shell temperature must not exceed the maximum level. Fuel element temperatures must not exceed limits	Thermal analysis and analysis of pressure inside the MPC confirmed that the MPC is resistant to the accident

Orig. Inv. No.	Signature, Date	Repl. Inv. No.

Initiator Event (IE)	IE Parameters	Reception Criteria Used for Analysis	Analysis Results
		set for accident conditions. Preserved integrity of the containment shell of the MPC	
Flying objects generated by other accidents	Site conditions	An impact of a flying object must not result in the damage that will increase the exposure rate at the site boundary.	The impact of such an event is lower than the impact of flying objects carried by a tornado
Sticking of spent fuel assemblies	Fuel basket cell size and spent fuel assembly size	Making sure that a spent fuel assembly fits basket cells easily	Taking into account the MPC geometry and manufacturing tolerances, it can be concluded that this event is not probable.
Operator’s mistake when loading spent fuel assemblies	Incorrect positioning of a spent fuel assembly in the fuel basket	The fuel element shell temperature must not exceed the maximum level.	Thermal analysis of a HI-STORM 190 cask for incorrect positioning conditions confirms that the temperature and pressure limits are met
Falling objects	Potential collapses of building structures and process equipment	The impact of the object fall must not result in the damage that will increase the exposure rate at the site boundary.	The impact of falling objects on HI-STORM 190 in case of the long-term storage is less unfavorable than the impact from flying objects carried by a tornado
Failure of load gripping mechanisms when moving spent fuel assemblies	Load lifting capacity and duplication	Assurance of the necessary load lifting capacity and duplication	No need to analyze this accident because lifting and crane equipment is protected against once-off failures
Falling of HI-STORM 190	Lifting devices and HI-STORM 190 are designed to prevent falling	Preserved integrity of the containment shell of the MPC.	Falling of HI-STORM 190 will not lead to

Orig. Inv. No.	Signature, Date	Repl. Inv. No.

Initiator Event (IE)	IE Parameters	Reception Criteria Used for Analysis	Analysis Results
	loaded HI-STORM 190	The event must not result in a substantial increase in the exposure rate at the site boundary	emergency conditions or a design-basis accident.

Measures For Prevention Of Emergencies And Accidents

Prevention of emergencies and accidents at the CSFSF if primarily ensured by:

- design of MPC, HI-STAR, and HI-STORM;
- design solutions for the transportation and technological operations with SNF at the CSFSF;
- selection of equipment involved in the SNF management operations, in accordance with the regulatory requirements;
- prevention of human errors;
- reliability of structures of the acceptance building and storage platforms to meet the requirements for seismic loads [124];
- implementation of regulations and instructions on the CSFSF operation.

Technical solutions relating to the design and materials of the MPCs, HI-STARs and HI-STORMs are described in para 10.4.1.1 of this Section.

All the equipment involved in the SNF management at the CSFSF is classified as important for the safety of operations. It is designs with significant reserve and/or its security functions are duplicated in order to prevent new initiating events and limit their consequences.

The design solutions for the transportation and technological operations with SNF at the CSFSF are set out in Part 1, “Technological Part. Spent Nuclear Fuel Handling”, Volume 3 of this project.

The preparation of the instructions for handling operations is based on the experience of Holtec in SNF management. In order to prevent human error, organizational measures will be taken in combination with the experience of previous situations.

Reception building is classified as Category 1 structure in terms of nuclear and radiation safety according to PiN AE 5.6 [7] and seismic Category 1 under PNAEG 5-006-87 [124]. It is designed to withstand the loads during MDE (once in 10,000 years), which corresponds to the magnitude 6 earthquake at the CSFSF site. Thus, in accordance with the definition set out in PNAEG 5-006-87, the structures of seismic Category 1 must retain their protective and containment functions after the magnitude 6 earthquake.

[142] shows that the HI-STORM storage cask can withstand the load during the magnitude 7 earthquake without tipping and loss of protective properties.

During operation of the CSFSF, in order to ensure compliance with regulations and operating instructions, certain organizational arrangements will be implemented. The organizational arrangements are set out in Section 8.

The sufficiency of measures for prevention of emergencies and accidents is substantiated in the PSAR.

Out of beyond-design-basis accidents listed as initiator events in NP 306.2.105-2004 [39], only an initiator event associated with the development of a self-sustained chain reaction is applicable to CSFSF.

The subcriticality of the spent nuclear fuel management at the CSFSF subject to all conservative assumptions stated in requirements of NP 306.2.105-2004 [39] has been demonstrated in Report On The Results Of Accidents Analysis HI-2083899 [142] and Report On The Subcriticality Analysis HI-2083899 [136]. More details on the BDBA at the CSFSF are supplied in the PSAR.

In order to limit and mitigate the consequences of the BDBA, the emergency plan for the CSFSF is implemented to meet the requirements of NRBU-97 [101].

The emergency plan should at least include measures to create the necessary emergency supplies, including:

- dosimetric and radiometric equipment;
- emergency PPE kits, respiratory protective equipment;
- emergency stock of directly indicating dosimeters;
- vehicles and supply of fuels and lubricants;
- pharmacological means of radiation protection;
- communication and management means;
- decontamination means.

To reduce the risk of BDBA, measures related to physical protection of the nuclear units, consisting of a set of organizational, legal, operational, investigative, and technical activities.

10.7.5 Radiation Safety During Decommissioning

Radiation safety during decommissioning of the CSFSF will be ensured by the following design solutions.

The dry type storage eliminates the formation of large amounts of liquid radioactive waste and, accordingly, the possibility of contamination of the premises is not expected.

The SFAs are stored in sealed MPCs, so contamination of HI-STORM and, respectively, radiation exposure of personnel during dismantling will be minimal. The use of cask storage limits the possibility of contamination of large areas even in the event of depressurization of individual MPCs.

The surfaces in the premises in the areas of MPC management will be covered with easily decontaminated materials, so periodic decontamination of the premises will effectively minimize the radiation exposure of personnel during decommissioning.

The effective special ventilation system will prevent the spread of radioactive substances in the premises of the reception building during normal operation and possible accidents.

The technological process does not involve the use of toxic and other potentially hazardous non-radioactive substances.

Due to the fact that the main impact on the staff in the operation of the CSFSF is from the external gamma-radiation, the radiation dose rates for the personnel during decommissioning (after removal of the SFA) will be significantly lower than the dose rates during operation. Basic radiation dose rates can be obtained due to decontamination of premises and equipment in the high security zone located in these areas.

After work on decontamination of the contaminated equipment and premises, the radiation dose rates will be significantly reduced.

Decommissioning concept must be included in a separate section at the design stage to adequately substantiate the design, organizational and technical solutions to ensure decommissioning of the CSFSF with lowest possible radiation exposure to personnel, population and the environment. The concept will consider the general aspects of decommissioning as defined in NP.306.1.02/1.004-98 [162], with possible detailing at the design stage.

It will include the optimization of layout of premises and arrangement of systems and components of the installation with regard for the need to remove large fragments of HI-STORMs, free remote disconnection and transfer of the MPCs, and placement of the equipment for decommissioning.

The basic equipment needed for radiation protection during decommissioning will include:

- equipment required to prevent contamination of the premises (including local ventilation and filtering systems);
- equipment for radiation dosimetric monitoring;
- equipment for monitoring the dose rates and surface contamination in the workplaces, contamination of components and materials during dismantling;
- equipment required to monitor the volume activity of aerosols in the workplaces.

11. ENGINEERING AND TECHNICAL MEASURES OF CIVIL PROTECTION (CIVIL DEFENSE)

The centralized storage of spent nuclear fuel from VVER nuclear power plants of Ukraine, in accordance with the Resolution No. 6 of the Cabinet of Ministers of Ukraine dated 09.01.2014 [51], is classified as facility, designing of which is to be carried out in view of the requirements for engineering means of civil protection.

In accordance with the requirements of paragraph 6.1 of DSTU B.A.2.2-7:2010 [52], Section ETM of CP was developed as a separate volume as part of the project documentation — Volume 10, “Engineering And Technical Measures Of Civil Protection (Civil Defense)”, consisting of Part 1 “Executive Summary” (571402.201.010-GO01) and Part 2, “Structures Of Civil Protection (Civil Defense)” (571402.202.010-GO02).

The engineering measures of CP developed based on the specification for development of ETM section on CP (hereinafter — Task) issued by GSChS of Ukraine (Annex to the letter № 16-4231/162 of 23.06.2015) taking into account the requirements of the relevant regulations and legal acts. The specified task is set out in Annex A, Volme 10.1, “Engineering And Technical Measures Of Civil Protection (Civil Defense)”. Part 1. Executive Summary.

In accordance with the task, the site under design is not classified in terms of civil protection. After the completion of the facility, the site will be considered as of Civil Protection category in accordance with the procedure No. 227dsk defined by the Cabinet of Ministers of Ukraine of 02.03.2010.

The territory, in which the designed site is located (Kiev region, Ivankiv district, zone of exclusion as a result of the Chernobyl disaster), in accordance with the Resolution No. 87-2 of Cabinet of Ministers of Ukraine of 25.02.2015 is not classified as civil defense means (Task, paragraph 2).

At a distance of 20 km from the construction site, there is SSE "Chornobyl NPP", classified as the site of the first category of civil protection in accordance with the Order No. 1dsk of the State Agency of Ukraine for the Exclusion Zone Management of 07.05.2014, which, pursuant to paragraph 1.4 of DBN V.1.2-4-2006 [53], substantiates the location of the site under design within the boundaries of the possible hazardous radiation contamination zone (Task, paragraphs 3, 4).

On the basis of the Task requirements and DSTU B.A.2.2-7:2010 [52] as part of the project documentation, a set of technical measures of CP, detailed in Volumes 10.1 and 10.2 under the design solutions in the field of civil protection (civil defense), in accordance with the requirements of DBN V.1.2-4-2006 [53], and the design solutions aimed at prevention of technological and natural emergency situations, including as follows:

- on the basis of materials of the Task, taking into account the requirements of DBN V.1.2-4-2006, the substantiation of classification of the facilities under design and the surrounding objects in terms of Civil Protection and identified of possible zones of hazard have been produced;
- based on the requirements of DBN V.1.2-4-2006 [53], the minimum acceptable degrees of fire resistance for the production, storage and office buildings of the facilities under design;

- construction of two shelters of Class A-IV with a capacity of 100 people each equipped with ventilation systems designed to operate in 1 and 2 modes for civil protection (civil defense);
- equipment of the facilities under design with a local warning system;
- measures to prevent unauthorized interference with the activities at the facility;
- blackout procedures;
- measures to prevent the accidents at potentially dangerous facilities (storage of 10 m^3 of HFL);
- measures to control the radiation situation and meteorological factors on the CSFSF site;
- the development of project documentation is based on the requirements of construction in seismic areas (MDE of magnitude 6).

In accordance with Art. 31 of the Law of Ukraine “On Regulation In Urban Planning” [54], Section of ETM CP is subject to expert examination under design documentation in accordance with the procedure established by DSTU-NB A.2.2-10:2012 [55].

12. RELIABILITY AND SECURITY PROVISIONS

12.1 General Site Security Provisions

Operational safety of buildings and structures, in accordance with paragraph 5 of DBN V.1.2.-9-2008 [56], is provided for by the implementation of measures to exclude (prevention) injuries or death of personnel resulting from:

- drop as a result of sliding, stumbling, entanglement of changes in elevation;
- injury or death as a result of contact with construction site or its parts;
- burns as a result of contact with parts of the construction site or equipment;
- electric shock as a result of lightning strikes or overvoltage of power supply systems;
- accidents related to moving vehicles.

Excluding of personal injuries as a result of falling after slipping or entanglement is achieved by:

- exclusion of elevation differences and obstacles in the passages used by the personnel;
- installation fences along the roof perimeters in accordance with paragraph 6.13 of DBN B.1.1-7-2002 [17];
- use of flooring materials that exclude sliding and slipping;
- lighting in accordance with the requirements of paragraph 6 of PUE [16];
- providing of necessary slope, size and tread of stairs in accordance with paragraph 5 of DBN B.1.1-7-2002 [17].

Prevention of injury or death by contact with the building structures is ensured through the elimination (preventing) of sharp and cutting edges and the use of appropriate protection means (GOST 12.4.059-89 [57]) during repairs.

Lightning protection is provided in accordance with DSTU B V.2.5-38:2008 [26].

Provision of levels I and II of protection with the sufficient reliability of protection against direct lightning strikes of probability 0.99 and 0.95, respectively.

For outdoor casks and refueling stations separate lightning rods (of level II protection) are planned.

Lightning protection of buildings by means of grounding metal structures of buildings or through lightning protection grid on the roofs of buildings (level II protection).

The lightning protection grid is to be made of round steel with a diameter of 8 mm, with a mesh of 10x10 m.

Current taps (round steel with a diameter of 8 mm) from the lightning protection grid are to be laid along the walls of buildings along the perimeter at a distance of no more than 15 m from each other and attached to the outer grounding contour.

Earthing devices of lightning protection are combined with protective grounding of the buildings and structures.

To protect against secondary effects of lightning (introduction of high potentials) and static electricity, all the surfaces and underground communications at the entrance to the structures are connected to earthing devices.

To ensure safe operation and maintenance of electrical installations, all metal dead parts, which are normally not energized, but which can become live in the event of insulation fault, must be grounded by attaching to the protective conductor of the mains zero.

Earthing must comply with the requirements of Chapter 1.7 of PUE [16] and SNiP 3.05.06-85 [60].

For the 0.4 kV network of power consumers, including lighting, the TN-C-S earthing system is adopted. Protective earthing of the lighting system is provided according to the requirements of PUE [16].

Protection against electric shock is provided by the protective circuit breakers in the electrical installations. The circuit breakers provide protection against electric shock in the following cases:

- decrease in electric insulation resistance below the specified limit;
- connection of the phase conductor to the appliance casing;
- person touching live parts of electrical installations.

In order to prevent accidents due to movement of transport, the following measures are implemented:

- vehicles movement is carried on strictly established routes approved by the site management;
- road pavement is expected to eliminate the possibility of slippage of the vehicles and its diversion to the footpaths;
- road signs are designed to warn about the required reduction in speed within the site;
- footpaths and roads marked by appropriate traffic signs and markings are planned for the personnel.

In the period of low temperatures, the roadways and footpaths should be cleared of snow and ice.

12.2 Ensuring Of Compliance With The Requirements Of Safe Operation Of The Facility At The Stage Of Development Of Design Documentation

Given the fact that, currently, there are no buildings, structures and facilities in operation on the site, there is no need for operation safety measures/

12.3 Reliability And Structural Safety Of Buildings And Structures

According to paragraph 4.1.3 of DBN V.1.2-14:2009 [49], the main requirement in determining the reliability of the construction site is its fitness for purpose and the ability to maintain the required performance for a set period of operation. These include:

- assurance of safety of human health and life, property and the environment;
- preserving of the integrity of the site and its major parts as well as compliance with other requirements ensuring the use of the site for its intended purpose and proper functioning of the technological processes, including the reliability of building structures and foundations, heat and sound insulation properties of enclosures, their tightness, and acoustic characteristics;
- enabling development of the site (for example, extension without reinforcement of existing structures or increase of production capacity) and its adaptation to changing technical, economic or social conditions;

- providing for the necessary level of convenience and comfort for the users and operating personnel, including the requirements for climatic conditions in the rooms (ventilation, temperature, humidity, lighting, etc.), as well as the accessibility for inspection, repairs, replacement and upgrading of separate elements;
- risk limitation by meeting the requirements of fire resistance and reliability of safety devices, life-support facilities, and engineering structures.

The compliance with these requirements is ensure by the following means:

- implementation of OSMS at the CSFSF;
- training and testing of staff on labor protection;
- providing of the working places with necessary documentation in accordance with the requirements of organizational and administrative procedures of DP NAEK Energoatom;
- development of guidelines and emergency plans, training and instruction of the staff on the actions of emergency procedures and situations;
- arrangement for systematic monitoring of technical state of structures, buildings and facilities;
- arrangement for periodic maintenance and technical inspection of equipment systems;
- certification of workplaces for compliance with the working environment's requirements according to the regulatory documentation, development (if necessary) of optimization measures.

While building a centralized storage facility for spent nuclear fuel, certain design solutions are applied to ensure safe performance of technological operations with a view to ensuring the reliability and structural safety of buildings and structures.

Reliability, including the durability and survivability, is provided by simultaneous compliance with the requirements regarding the selection of materials, design and volume-planning decisions, methods of calculation, design and quality control of the works.

12.4 Specific Features Of Enforcement Of Requirements As To Operational Safety During Design Of Structures Located In The Areas With Unfavorable Natural And Technological Phenomena

Within the CSFSF site, no physical/geological processes and phenomena that would affect the condition of the area negatively have been observed. The erosion of soil, gullies and landslides is absent due to the minor difference between absolute ground surface elevations (within 2.0 m) and dense vegetation. No swamp development and waterlogging of the area have been observed (underground waters occur at depths of 12.2 to 19.2 meters).

Since the surveyed area in geological terms consists of well permeable sandy soils, the design level of underground waters was assumed to be 1.0 m higher than the level recorded during the survey to account for seasonal fluctuations. Temporary water table of the perched water may form in the thick deposits on top of the impermeable layers of clay soils during periods of intensive rainfall or in case of leakage from water lines.

In terms of the complexity of soil conditions, the construction site is categorized as Category II in accordance with Annex Zh to DBN A.2.1-1-2008 [61].

No changes in geological conditions are expected in the course of construction and operation of the storage facility.

Compliance with the requirements of DBN V.1.1-3-97 [2] as to engineering protection of the CSFSF construction site is ensured by a number of activities, namely:

- provision for required quality of materials, structures, products and works during construction of external and internal water-bearing networks by means of initial, current and final acceptance control;
- high-quality waterproofing of foundations of buildings and structures, including underground structures;
- collection and diversion to storage tanks of rainwater and wastewater from all the areas and paved roads.

12.5 Safety Barriers And Prevention Of Accidents In Buildings And Structures

According to the requirements set out in Section 4.5.2 of DBN V.1.2-14:2009 [49], the security of the site is ensured by implementation of the principle of defence in depth based on the use of barriers that are sequentially activated and operate independently performing the following functions:

- prevention of the occurrence of overloads, failures and accidents;
- provision for emergency handling of overloads and ensuring durability and functioning (possibly with the deterioration of the quality parameters or after renovation) of the main part of the site;
- prevention of explosive ruptures and failures as well as localization of consequences of the accident.

At the design stage, the implementation of the principle of defense in depth is carried out through the following organizational and technical measures:

- site selection for the object;
- establishment of sanitary-protection zone and surveillance zone around the facility, provision of fire breaks, etc.;
- development of the project on the basis of revised data on the possibility of the emergence and nature of catastrophic impacts;
- use of special safety systems;
- provision for required quality of materials, structures, products and works by means of initial, current and final acceptance control;
- operation of the facility in accordance with the operational documentation;
- provision of good condition of important security-related elements, devices and systems by means of proper maintenance;
- timely diagnosis, assessment of technical conditions and implementation of necessary measures to eliminate the detected defects and damage;
- measures to prevent possible causes of accidents, and in the event of accidents — localization of consequences;
- preparation and implementation (if necessary) of emergency plans at the facility and beyond, including the activities involving the population;
- ensuring the required level of staff training.

According to the experience of operation in the operational phase, the maintenance of security barriers in good condition is to be provided by the following activities:

- ensuring the required quality of works by means of quality system implementation;
- operation of the facility in accordance with the operational documentation;

- provision of good condition of important security-related elements, devices and systems by means of proper maintenance maintenance and repair according to maintenance schedules approved by the enterprise management;
- timely diagnosis, assessment of technical conditions and implementation of necessary measures to eliminate the detected defects and damage;
- measures to prevent possible causes of accidents, and in the event of accidents — localization of consequences in compliance with the acting guidelines for emergency situations;
- preparation and implementation of emergency plans at the facility and beyond, including the activities involving the population, as stated in the “Emergency Plan”.

12.6 Specific Features Of Assurance Of Safe Operation Of The Architectural Object At The Stages Of Construction And Installation

Construction of the CSFSF will be performed within the perimeter of temporary fencing, which will be built during the preparatory period. To ensure safety of the construction site and to prevent possible illegal actions within the facility, the following will be provided:

- installation of temporary checkpoints with round the clock security at the entrance gate and places of passage of the construction personnel;
- security lighting on the construction site and along the perimeter fence to provide for necessary visibility of the area, perimeter zones of the building and production area at night.

To ensure security at the stage of construction and installation works in accordance with the requirements of Section 6 of NPAOP 45.1-1.12-01 [62], the following activities should be performed:

- fencing and installation of safety signs to inform the workers on the borders of the construction and installation work sites;
- establishment of routes to work places for the staff;
- definition and allocation of transportation means, establishment of traffic routes. The speed of traffic on the construction site should not exceed 10 km/h; when cornering and while moving in reverse, the speed should be no more than 5 km/h;
- compliance with health and hygiene standards in accordance with the procedures established for the existing enterprise;
- identification of premises for temporary storage and domestic purposes;
- identification of places and routes for dumping of excavated soil and debris.

All construction and installation works must be carried out strictly in accordance with the specially designed project of works in compliance with the safety regulations set out in DBN A.3.2-2-2009 [63].

12.7 Operating Safety Requirements At The Stage Of Use Of The Site For Its Intended Purpose Within The Prescribed Period Of Operation

Safety of operation of the facility during its intended use is ensured by the implementation of a system of maintenance of buildings, structures, equipment, systems, as well as systematic monitoring of the territory condition.

The purpose of maintenance and repair work is to ensure safe operation of the systems during the design service life of the CSFSF — 100 years.

The main objects of maintenance in the systems are:

- buildings and structures;
- thermal and mechanical equipment of the technological systems;
- transport and processing equipment;
- storage area and HI-STORM 190 UA storage casks;
- electrical engineering systems;
- control and monitoring systems.

The maintenance tasks are as follows:

- operational control/monitoring of the systems and their components;
- timely performance of repairs;
- timely implementation of measures to ensure the security of the CSFSF;
- development of proposals, conducting of work on improving the CSFSF technical operation, as well as the quality of all types of repairs.

At the CSFSF, it planned to implement a preventative maintenance system. The system of preventive maintenance of the CSFSF will be a set of organizational and technical measures to ensure supervision, care and all types of repairs carried out routinely. It is expected that the planned maintenance of the systems and component will take 2-3 working days a month. Once a year, the main works at the CSFSF will be suspended for maintenance and repair of the main technological equipment. It is assumed that the current repair of the equipment once a year will be combined with the terms of preventative maintenance. Current inspection rounds will be carried out once every shift.

In order to ensure adequate operational and sanitary condition of the territory, the buildings and structures, as well as the compliance with the environmental requirements of Section 6.1 of GKD 34.20.507-2003 [64], the following systems and components should be kept in good condition:

- surface and groundwater drainage system all over the site, including the building and structures;
- dust, radioactive gases and aerosols emission treatment systems;
- facilities for treatment of polluted wastewater and oily sewer;
- water-supply, sewerage, and drainage systems;
- railroad tracks and crossings, roads, fire driveways, access to fire hydrants, crosswalks and other;
- basic and operational benchmarks and station marks;
- piezometers and monitoring wells to monitor groundwater regime;

- radiation monitoring systems on the territory of the sanitary protection zone and the surveillance zone;
- set engineering and technical means of protection (fencing, lighting, security checkpoints, office premises);
- lightning protection and grounding systems.

Furthermore, landscaping and land improvement should be carried out systematically.

The industrial buildings and facilities of the CSFSF must be kept in good condition to provide for long-term reliable use for intended purposes in compliance with the requirements of sanitary norms and occupational safety regulations.

In accordance with the existing practice of DP NAEK Energoatom, the safe operation of buildings and structures is provided by the following means:

- organization and conducting daily rounds and inspections;
- organization of periodic general supervision;
- organization of planned surveys of structures;
- organization and carrying out repairs.

Twice a year (in spring and autumn), along with the systematic monitoring of the CSFSF, the specialized committee should carry out overall technical inspection of buildings and structures to detect defects and damages, and in case of disasters (hurricane winds, large showers or snowfalls, fires, earthquakes, etc.) or accidents — extraordinary inspection of the facilities should be conducted by the persons responsible for their operation.

Technical inspection in spring should specify the volumes of repair of buildings, structures and plumbing systems during summer, as well as the volumes of overhaul to be included into the plans for the next year. In autumn, the technical inspection shall verify the preparation of buildings for winter.

The monitoring of buildings, structures and foundations should involve the monitoring of the state of bearings, expansion joints, welded, riveted and bolted joints in steel structures, joints and fixings precast in concrete, rebar and concrete in the reinforced concrete structures (for corrosion or deformations), crane structures and sites subject to dynamic and thermal loads and impacts. In case of detection of cracks, fractures and other signs of damage of structures, such structures should be monitored with the use of marks and instrumental measurements. The information about detected defects should be registered in the technical condition logs of the buildings and structures with the indication of terms of elimination of defects detected.

Roofs of buildings in spring and autumn should be cleaned of debris; the rain water collection systems should be cleaned and their performance should be checked.

Building structures of the main production buildings and facilities on the list approved by the head of the CSFSF, are subject to technical inspection by a specialized organization once every five years, as provided for in paragraph 6.2.3 of GKD 34.20.507-2003 [64].

Monitoring of the condition of the foundations, in accordance with the requirements of paragraph 6.2.5 of GKD 34.20.507-2003 [64], shall be carried out as follows:

- in the first year of operation — three times a year;

- in the second year — twice a year;
- further on and until stabilization of the foundation — once a year;
- after stabilization (yield of 1 mm a year or less) — once every five years.

In spring, all the water-diversion networks and devices should be inspected and prepared for the meltwater passage; the cable and pipe ducts, ventilation ducts in the walls of buildings must be sealed, and the pumps should be ready for use.

The groundwater regime monitoring — the monitoring of water levels in the monitoring wells (piezometers) — should be carried out as follows:

- during the first year of operation — at least once a month;
- in the following years — depending on the groundwater level changes, but at least once a quarter.

The water temperature measurements and water sampling from wells for chemical analysis should be carried out in accordance with the instructions.

The groundwater radioactivity monitoring should be carried out in accordance with the instructions issued by the department (service) of radiation safety and the sanitary requirements established by the supervisory bodies. The results of observations should be entered in a special register.

Te railroad tracks must be kept in good condition and maintained in accordance with the regulations on technical operation of the railways.

The maintenance of thermal mechanical equipment involves the following procedures:

- current maintenance;
- current repairs;
- overhaul.

Current repairs and overhaul to be carried out in accordance with the requirements of RG-D.027.412-10 [65], namely:

- maintenance and current repair of equipment — once every year;
- overhaul — once every four years.

The frequency of maintenance and repair of transport and technological equipment, in accordance with the requirements of RG-D.027.412-10 [67], may be assumed as follows:

- routine maintenance — at least once a year;
- current repairs — at least once every eight years;
- overhaul — at least once every 16 years.

Hoisting machinery, equipment and accessories should pass technical inspection in the amount determined by paragraphs 7.3, 7.4 of NPAOP 0.00-1.01-07 [66].

For electrical equipment, the maintenance and repair intervals may be adopted in accordance with the requirements of RG-D.027.412-10-02 [67], namely:

- factory-assembled switch-gear (cabinets, transformers, switches):
  - current repairs — once a year;
  - overhaul — once every six years;
- cable lines:
  - routine maintenance — once a year;
  - current repairs — once every three years;

- overhaul — basing on the results of high-voltage tests, the technical condition of cable lines, and standard service life of the cables of the type;

- cable ducts and steel structures:
  - routine maintenance — once a year;
  - current repairs — once a year;
  - overhaul — once every 20 years;
- alerting devices:
  - current repairs of lighting fixtures — once a year;
  - overhaul of voltage stabilizers — basing on the results of high-voltage tests, the technical condition of cable lines, and standard service life of the equipment of the type;
- UPS devices (the periodicity is based on the current practice for the Ukrainian nuclear power plants in accordance with RG-D.027.412-10-02 [67]):
  - maintenance 1 — once a month;
  - maintenance 2 — once a year;
  - maintenance 3 — once every 15 years.

For the elements of monitoring and control systems, the following maintenance and repair periodicity (in accordance with RG-0.05-412-11-01 [68]) can be accepted:

- computing systems (servers, workstations, desktops, gateways and so on)
  - maintenance 1 — once a month;
  - maintenance 2 — once every three months;
  - maintenance 3 — twice a year;
  - maintenance 4 — once a year;
  - the need for repair of computer systems is determined based on the results of technical condition monitoring, carried out during routine maintenance or when troubleshooting failures. The recommended range of works for maintenance 1-4 for the computer systems components is set out in Annex to M RG 0.05-412-11-01 [68]:
- instrumentation components:
  - maintenance — twice a year;
  - current repairs — once a year;
  - overhaul — once in 6-10 years (only for those items, for which this type of repair is provided for in accordance with the manufacturer's instructions);
- instrument panels and cabinets:
  - maintenance — twice a year;
  - current repairs — once a year;
  - calibration of measuring channels — once a year;
  - checks of resistance of the cable insulation — once every four years.

The periodicity of maintenance and repair of equipment and the range of works to be confirmed/determined in accordance with the manufacturer/supplier’s documentation.

Maintenance of the HI-STORM 190 UA casks is to be performed in accordance with the requirements for maintenance and operation developed by Holtec and approved under Special Program.

The scope of HI-STORM maintenance comprises:

- monitoring of the state of HI-STORM, including:
  - cleaning of the input ventilation ducts of dust, snow, etc.;
  - cleaning of the output ventilation channels;

- maintenance of temperature sensors (replacement for inspection and calibration);
- inspection of the outer surfaces of HI-STORM coating;
- monitoring and maintenance of radiation monitoring tools installed on the storage site;
- clearing of the site of foreign objects (snow, leaves).

Periodicity of service:

- visual inspection of the storage area is to be conducted daily;
- monitoring of the temperature measuring equipment — according to the passports of devices, but not less than 1 time in 3 years;
- remote monitoring of the MPC condition using video cameras through upper air ducts during inspection of the upper air ducts — not more than once every four years.

Inspection and testing of the equipment at the spent fuel storage facility are carried out according to the operating instructions by the manufacturers of equipment in compliance with the schedule of technical condition checks for transport and technological equipment.

Support Of Maintenance Works

The following repair shops will be provides for servicing the CSFSF equipment:

- electrical and mechanical workshop for clean equipment, not contaminated by radioactive substances in the maintenance building;
- workshop for equipment contaminated with radioactive substances in the reception building;
- workshop for maintenance of road transport in the garage.

The workshops will be equipped with the appropriate machine tools and instrumentation. The workshops will be equipped with manual hoists for mechanization of repair works.

In order to provide for repair, the temporary working lighting using ~12 V (sockets network) is planned to be installed in the following buildings and structures of the CSFSF:

- reception building;
- maintenance building with the MPC storage facility;
- electrical equipment building;
- guardhouse;
- administrative building;
- fire water supply pumping station;
- garage.

The temporary working lighting is provided in the premises of ventilation chambers, transporter parking location, maintenance and repair workshops, electrical rooms, machinery rooms, where additional lighting is needed during inspection or repair of the technological equipment. Power supply is provided from the main lighting network of the related facilities through step-down transformers installed in the appropriate boxes.

Detailed description of the power supply systems is presented in Volume 5, “Electrical Part” of this project.

In order to meet own needs for compressed air at the CSFSF site, a system of compressed air is envisaged.

The consumers of compressed air are located in the following buildings:

- the reception building;

- maintenance building with an MPC warehouse;
- garage (for the transporter and automobiles).

Preparation and delivery of compressed air is intended to provide reliable supply of compressed air of required quality, pressure and flow for the pneumatic drives of the technological equipment provided by Holtec, as well as for repairs.

Detailed description of the compressed air system is shown in Volume 3.3 “Technological Part”, Part 3 "Utilities" of this project.

Storage facilities for tools and spare parts will be provided in the maintenance building with the MPC warehouse and in the reception building.

12.8 Providing For Security During The Facility Commissioning

The fully complete objects should be accepted for operation in accordance with “The Procedure For Acceptance For Operation Of Completed Construction Objects”, approved by Resolution № 461 of the Cabinet of Ministers of Ukraine of April 13, 2011.

For the period of construction, installation and commissioning, the Customer (consumer) shall provide qualified technical supervision and interim acceptance of the units of equipment and facilities, including the hidden works.

The construction company is to supply the Customer with the following technical documentation:

- design and estimate documentation (as-built drawings, cost estimates);
- work logs;
- statements of interim acceptance and inspection;
- statements of acceptance of hidden works;
- other mandatory documents required under DBN.

In accordance with the requirements of Section 8 of PNAE G-14-029-91 [69], the commissioning of the CSFSF will be carried out with the permission of the State supervisory authorities.

The completeness of the storage facility prior to putting into operation will be checked by:

- the working commission of the CSFSF;
- the state supervisory authorities.

The working commission of the CSFSF appointed by order of the head of inspection, will check:

- compliance of the work performed with the project;
- availability of equipment, equipment test reports and certificates of completion of commissioning works;
- availability of the necessary documents in accordance with Section 7
- of PNAE G-14-029-91 [69] and their compliance with the design;
- level of training of the personnel, the availability of exam protocols and the order on admission to works.

The resolution of the commission is produced in the form of a statement.

The bodies of state supervision shall check the CSFSF readiness, personnel and documentation, and present the inspection test results in due course.

DP NAEK Energoatom will grant the permit for operation of the CSFSF on the basis of statement of commissioning by the State Acceptance Commission provided there are relevant documents produced by the State supervision authorities.

The documents of CSFSF commissioning as well as all the construction and assembly documentation must be kept at the facility during the entire life cycle of the CSFSF.

13. IDENTIFICATION OF POTENTIALLY HAZARDOUS FACILITIES

13.1 General Provisions

The risk of emergencies of technological nature is largely determined by the condition of potentially hazardous facilities.

Identification of potentially hazardous facilities (PHF) is performed in all enterprises owning or using facilities for use, production, processing, storage or transportation of hazardous substances. PHF identification is also done for all enterprises that have intention to start construction of such facilities.

The legal basis for the identification of PHF are the Code of Civil Defence of Ukraine [74], the Law of Ukraine “On Hazardous Facilities” [75], the rules of technological safety in the field of civil protection in enterprises, organizations, institutions, and hazardous areas [76].

PHF identification implies analysis of the structure of the facility and the nature of its operation. An important task at the stage of PHF identification is to determine the characteristics (properties) of PHF in terms of possible adverse impact on the production, population and the environment.

The process of identification shall consider and taken into account internal and external sources of potential hazard.

Internal sources determine the danger of buildings, structures, equipment, processes, objects and substances circulating in the facility.

External hazards that are not directly related to the operation of the facility, but may cause emergency situations and have a negative impact on their development. External sources include natural phenomena and accidents on the nearby facilities.

The analysis allows to establish the presence or absence of hazards, which in certain circumstances may cause emergencies, as well as to determine their possible levels.

The facilities are identified as potentially hazardous, if they contain at least one source of hazard that may result in emergency situation of facility-specific, local, regional or state level.

PHF identification is carried out in accordance with the Methodology For Identification Of Potentially Hazardous Facilities [77].

In the case of identification of facility as potentially hazardous, the high-risk factor is also identified.

Identification of the high-risk factor (HRF) is performed in accordance with the Procedure For Identification And Registration Of High-Risk Factors [78].

13.2 Identification Of Potentially Hazardous Facilities

PHF identification is carried out in accordance with the Methodology For Identification Of Potentially Hazardous Facilities [77] and involves the following stages:

- selection of emergency codes, the occurrence of which is possible at the facility;
- analysis of indicators of emergency signs and determination of threshold values;
- determination of the results of analysis of hazards, which under certain conditions could cause emergency situations;

- definition of hazards for each of the specific sources;
- determination of a list of hazardous substances used at the facility, their amounts and hazard classes;
- evaluation of the distribution zone and possible consequences of emergency situations;
- establishment of the most probable emergency levels;
- determination of proper state registers (inventories) to register the hazardous facilities;
- determination of the compliance of the facility with the regulations in hazardous facilities determination.

13.2.1 Selection Of Emergency Classification Codes, The Occurrence Of Which Is Possible At The Facility

Selection of the code of emergency at the facility is carried out in accordance with the Classifier of Emergencies (DK 019:2010) [79]. Emergency Codes selected for the facility under design are listed in Table 13.1.

Table 13.1 **— Emergency Codes Of Possible Hazards**

Emergency	**Name Of Emergency**
10000	MAN-MADE EMERGENCY
10100	MAN-MADE EMERGENCY OR DISASTER ON TRANSPORT (EXCEPT FIRE AND EXPLOSION)
10110	Emergency on transport with the release (threat of release) of hazardous and harmful
10112	Emergency on transport with the release (threat of release) of radioactive
10200	EMERGENCIES DUE TO FIRE, EXPLOSIONS
10210	Emergencies due to fire, explosions in buildings and structures
10211	Emergencies due to fire, explosion in buildings, on technological lines or technological equipment of industrial facilities
10212	Emergencies due to fire, explosion in non-residential buildings
10220	Emergencies due to fire, explosion at the facility for exploration, extraction, processing, transportation or storage of flammable, combustible and explosive substances
10230	EMERGENCIES DUE TO FIRE, EXPLOSIONS ON TRANSPORT
10231	Emergencies due to fire, explosion on railways
10250	Emergencies due to fire, explosion on radiation, chemically or biologically hazardous facility without spillage (release) of hazardous substances
10500	EMERGENCIES WITH THE RELEASE (THREAT OF RELEASE) OF RADIOACTIVE SUBSTANCES
10520	Emergencies with the release (threat of release) of radioactive substances at the enterprises of nuclear-fuel cycle (except nuclear power plants)
10600	Emergencies due to sudden destruction of buildings and structures
10610	Emergencies due to destruction of elements of transport infrastructure
10620	Emergency due to destruction of buildings or structures of industrial purpose
20000	NATURAL EMERGENCIES
20100	GEOPHYSICAL EMERGENCIES
20110	Emergencies related to earthquakes
20300	METEOROLOGICAL EMERGENCIES
20310	Meteorological emergencies related to precipitation

Emergency	Name Of Emergency
20320	Meteorological emergencies, temperature-related
20330	Meteorological emergencies, other
20700	MEDICAL-BIOLOGICAL EMERGENCIES
20720	Emergencies related to poisoning of people
20721	Emergencies related to poisoning of people as a result of use of poor-quality food
20722	Emergencies related to poisoning of people as a result of use of poor-quality water
20723	Emergencies related to the poisoning of people with toxic or other substances (individual cases)
30000	SOCIAL EMERGENCIES
30100	ARMED ATTACKS, SEIZURE AND RETENTION FACILITIES OF STATE IMPORTANCE (MOST IMPORTANT AND IMPORTANT STATE FACILITIES) OR REAL THREATS OF SUCH ACTIVITIES
30170	Armed attacks, seizure and retention of nuclear power plants, chemical industry facilities and facilities used to produce and store biohazardous materials or the threat of such actions
30500	EMERGENCIES INVOLVING DISAPPEARANCE OR THEFT OF WEAPONS AND HAZARDOUS SUBSTANCES FROM THE FACILITIES OF STORAGE, USE, PROCESSING OR DURING TRANSPORT
30510	Emergencies related to the disappearance or theft of firearms technical items from the facilities of storage, use, processing or during transport
30520	Emergencies related to the disappearance or theft of ammunition from the facilities of storage, use, processing or during transport
30530	Emergencies related to the disappearance or theft of armored vehicles from the facilities of storage, use, processing or during transport
30560	Emergencies related to the disappearance or theft of radioactive substances (also devices, equipment containing radioactive substances) from the facilities of storage, use, processing or during transport
30600	EMERGENCIES RELATED TO ACCIDENTS WITH PEOPLE
30610	Emergencies related to accidents in the performance of job duties
40000	MILITARY EMERGENCIES

13.2.2 Indicators Of Emergency Signs And Determination Of Threshold Values

Analysis of signs of emergency, selected in the previous step, and definition of their threshold values was performed using the classification features of emergencies [80]. The results are set out in Table 13.2.

Table 13.2 **- Indicators Of Emergencies And Their Thresholds**

Indicator No.	Description	Thresholds Value
1	Man-made emergency	

Indicator No.	Description	Thresholds Value
1.1	Death or injury to people (staff) due to explosions and fires (except in cases of fires and explosions in residential buildings and structures), destruction of underground structures (including the collapse of roofs in mines	2 or more people killed, 5 or more people injured.
1.2	Death or injury to people (staff) due to accidents, emergency events (except in cases of road traffic accidents) and other hazardous events (including casualties)	3 or more people killed, 10 or more people injured.
1.6	Immediate threat to life from hazardous (affecting) factors of emergency situation (accident event) leading to emergency evacuation of more than 50 people.	1 event
1.7	Emission dangerous chemicals of appropriate hazard class (corresponding to the level of toxicity), including dangerous goods (release from the technological equipment of the facility), which can create or creates affecting factors for vehicle (facility) personnel, the public or other environmental object	For dangerous chemicals of Hazard Class 3 — 0.1 t; for dangerous chemicals of Hazard Class 4 — 0.5 t.
1.8	Emission of radioactive substances from vehicles or damage to radioactive cargo (packaging, cask, etc.) related to traffic accidents (accident, fire or other hazardous event)	1 event
1.10	Accident on the railways (including subways), which lead to the collision of passenger or freight trains with other trains or rolling stock, running off the track of rolling stock of passenger or freight trains on hauls and stations, as well as death and/or injury of people	3 or more people killed, 10 or more people injured.

Indicator No.	Description	Thresholds Value
1.11	Accident on the railways (including subways), which lead to the collision of passenger or freight trains with other trains or rolling stock, running off the track of rolling stock of passenger or freight trains on hauls and stations, as well as damage to rolling stock to the extent of its decommissioning	3 or more items
1.12	Explosion (fire) during movement of a vehicle with explosive (flammable) substances, hazardous chemicals or petroleum products (with damage to containers (tanks, casks, packaging, etc.) of the dangerous goods	1 event
1.25	Fire (explosion), for the elimination of which, in addition to the forces and means of fire-rescue units or other emergency services, additional forces and resources involved in other groups of civil protection are required, and direct damages (estimated in accordance with the legislation) caused by fire (explosion) exceeded 0.5 thousand minimum wages	1 event
1.40	Accident at the facility, where nuclear materials are used, sources of ionizing radiation or radioactive wastes are stored, resulting in (possible) employees exposure to the effective radiation dose of more than 2 mSv/year (category A workers — more than 50 mSv/year)	1 event
1.41	Radioactive contamination of the environment due to radiation accident at the facility, where nuclear materials are used, sources of ionizing radiation or radioactive wastes are stored, resulting in (possible) population exposure to the effective radiation dose of more than 1 mSv/year	1 event
1.45	Nuclear or radiological accident, which represents a threat to Ukraine, reportable in accordance with the International Convention on Early Notification of Nuclear Accidents or pursuant to bilateral intergovernmental agreements	1 event

Indicator No.	Description	Thresholds Value
1.47	The collapse of more than 10% of a building or structure (bearing structures of the building) of the main production facility leading to consequences (responsibility) of Class CC2 or CC3	1 event
1.48	Failure of more than 10 percent of the total amount of main technological equipment on a manufacturing enterprises of strategic economical or state security importance due to the destruction (damage) of its buildings and structures	1 event
1.49	Suspension of production activities of the enterprises of strategic economical or state security importance due to the destruction of its buildings and structures used for production purposes (including transport infrastructure)	12 or more hours
2	Natural emergencies	
2.1	Death or personal injury (disease, poisoning) due to natural hazards or events of medical and biological nature	3 or more people killed, 10 or more people hospitalized.
2.2	Immediate threat to life from hazardous (affecting) factors of emergency situation of natural origin leading to emergency evacuation of more than 50 people.	1 event
2.3	Earthquakes in excess of background seismicity by 1 point	1 event
2.4	Earthquakes with intensity of more than 5 points on the MSK-64 scale in the places of location of high-risk facilities	1 event
2.31	Contraction of dangerous infectious diseases by people: dysentery and other intestinal infectious diseases of established or unknown etiology, salmonellosis, viral hepatitis A	3 or more people in organized communities within 3 days.
2.35	Cases of poisoning of 10 or more people with industrial dangerous chemicals or other hazardous substances	10 to 25 people — individual poisoning, 26 or more people — group poisoning;
2.36	Simultaneous poisoning of people of the same group as a result of consumption of food or water: - botulism, - same type toxicants, - wild mushrooms and plants or combination of toxicants of two or more species	1 or more people. 10 or more people. 5 or more people.

Repl. Inv. No.

Indicator No.	Description	Thresholds Value
3	Social emergencies	
3.1	Death or personal injury due to hazardous events (including accidents on the water)	3 or more people killed, 10 or more people injured.
3.4	Armed attacks, capture and holding of building of law enforcement bodies	1 event
3.8	Armed attacks or unauthorized actions by individuals with regard to nuclear facilities	1 event
3.13	Disappearance or theft of firearms of Destruction Categories 1 and 2 with ammunition	1 event
3.15	Disappearance or theft of grenades, artillery shells, mines, bombs or explosive charges	1 event
3.16	Disappearance or theft of armored vehicles	1 event
3.21	Disappearance or theft of dangerous chemicals, which can create or create affecting factors for facility personnel or other environmental objects	For dangerous chemicals of Hazard Class 3 — 0.2 t; for dangerous chemicals of Hazard Class 4 — 2 t;

13.2.3 Identification Of Hazards That May Be Sources Of Emergencies

According to the analysis of hazard sources, which under certain conditions (accident, violation of operating conditions, occurrence of natural hazards, etc.) can give rise to emergencies, relevant sources of hazard listed in Table 13.3 have been identified using the List of the main sources of hazards inherent in potentially dangerous facilities (Appendix 2 to Methods Of Identification Of Potentially Hazardous Objects [77]).

Table 13.3 — **Sources Of Emergency Situations**

Hazard Source Name	Hazard Source Analogue
Tanks with diesel fuel	Tanks, reservoirs, bottles and other containers with hazardous substances
Fuel dispenser	Technological equipment, associated with the use, production, processing or transportation of hazardous substances
Canisters with motor oils	Tanks, reservoirs, bottles and other containers with hazardous substances
MPC, HI-STAR, HI-STORM, HI-TRAC casks	Nuclear installations, facilities for radioactive waste management, sources of ionizing radiation
Lifting machinery	Stationary equipment for loading and unloading, lifting machinery

Hazard Source Name	Hazard Source Analogue
Railway facilities within the area	Station tracks and turnouts of railway stations, switching and crossing devices, cargo and passenger handling devices, marshalling yards, locomotives, wagons, and storage facilities

13.2.4 Definition Of Hazards Factors For Specific Sources Of Hazards

For each of the identified sources of hazard, the types of hazard have been identified on the basis of Annex 3, Methods Of Identification Of Potentially Dangerous Facilities [77]. See Table 13.4.

Table 13.4 — **Sources Of Emergency Situations**

Hazard Source Name	Hazard Type
Tanks with diesel fuel	Explosion, fire, chemical, environmental hazards
Fuel dispenser	Explosion, fire, chemical, environmental hazards
Tanks with diesel fuel for diesel power plants	Explosion, fire, chemical, environmental hazards
Canisters with motor oils	Fire, chemical, environmental hazards
MPC, HI-STAR, HI-STORM, HI-TRAC casks	Radiation hazard
Lifting crane	Physical hazard
Railway facilities within the area	Explosion, fire, chemical, environmental, radiation, physical hazards

13.2.5 Definition Of A List Of Hazardous Substance Used At The Facility, Their Amounts And Hazard Classes

For the facility in design, a list of hazardous substances used in the operation of the facility, their amounts and hazard classes have been identified according to GOST 12.1.007-76 [81] and GOST 19433-88 [82]. The results are set out in Table 13.5.

Table 13.5 **— List Of Hazardous Substances**

Hazardous Substance Name	Amount, tonnes	Hazard Class Under GOST 12.1.007-76 [81]	Hazard Class & Subclass Under GOST 19443-88
Diesel fuel*	8.06	4 (paragraph 5.1 of DSTU 3868-99 [83])	3, 3.3 (paragraph 4.3.1 of DSTU 3868-99 [83])
Motor oil*	0.07	4 (paragraph 7.5 of GOST 10541-78 [84])	-
Spent nuclear fuel	5648 (TM)	-	7
* — without regard for presence of hazardous substances (fuels and oils) in the railway rolling stock, technology and road transport serving the CSFSF			

13.2.6 Evaluation Levels Of Possible Emergencies

Based on the previously obtained data, the evaluation of distribution area in case of emergency for different identified initial hazards, possible consequences of emergencies and the highest possible levels of emergency have been made. The evaluation results are summarized in Table 13.6.

Evaluation of the zone of possible disaster was made using a conservative method and is to be refined on the basis of the materials developed pursuant to Order No. 122 of State Agency for Occupational Safety Supervision of 17.06.1999 [85] on Plans Of Localization And Liquidation Of Emergencies And Accidents.

Assessment of possible consequences of emergency situations for each of the identified hazard sources (in terms of number of dead and injured) was made on the basis of threshold values for the previously defined emergency situations.

The level of emergency for each of the hazard sources is established in accordance with the Procedure For Classification Of Emergency Situations By Levels [86] and the Classification Of Emergency Situations Of Natural And Man-Made Origin (Annex 4 to Methods Of Identification Of Potentially Hazardous Facilities [77]).

Table 13.6 **— Assessment Of Possible Consequences And Hazard Levels**

Hazard Source Name	Propagation	Number Of Lethal Cases,	Number Injured, people	Emergency Level
Tanks with diesel fuel	Within the facility territory	2 or more	5 or more	Local
Fuel dispenser	Within the facility territory	2 or more	5 or more	Local
Tanks for motor oil	Within the facility territory	2 or more	5 or more	Local
MSC, HI-STAR, HI-STORM, HI-TRAC casks	Emergency beyond the territory of the	-	-	National
Lifting crane	Within the facility territory	3 or more	10 or more	Regional
Railway facilities within the area	Within the facility territory	3 or more	10 or more	Regional

13.2.7 Identification Of State (Sectoral) Registers (Cadastres) Used For Registration Of The Facilities

Table 13.7 Lists the relevant registers (cadastres) used/not used for registration of the facilities under design in accordance with the List Of Approved State (Sectoral) Registers Of Ukraine (Annex 5 to Methods Of Identification Of Potentially Hazardous Facilities [77]).

Table 13.7 **— List Of State (Sectoral) Registers (Cadastres)**

Name Of State (Sectoral) Register (Cadastre)	**Registration Number (If Any)**
State Register Of Potentially Hazardous Facilities	Not registered, subject to registration
State Register Of High-Risk Facilities	Not subject to registration
Register Of Accident-Prone Production Buildings And Structures	Not subject to registration
State Register Of Ionizing Radiation Sources	Not registered, subject to registration
State Register Of Radioactive Waste	Not subject to registration
State Register Of Radioactive Waste Storage Facilities	Not subject to registration
State Cadastre Of Radioactive Waste Storage Facilities	Not subject to registration
Register Of Waste Generation, Treatment And Disposal Facilities	Not subject to registration
Register Of Waste Disposal Facilities	Not subject to registration

13.2.8 Identification Of The Facility's Relation To The Acting Regulations

The results of identification of relation to the regulations (need to meet the corresponding thereof) listed in paragraphs 14, 15 of Methods Of Identification Of Potentially Hazardous Facilities [77] are presented in Table 13.8.

Table 13.8 — **Relation Of The Facility To Certain Regulations**

Facility Covered (Not Covered) By RI	**RI Title**
Covered for identification Paragraph 1 (to the extent concerning compliance with Annex 2 to Regulatory Threshold Masses Of Toxic Substances In Identification Of HRF)	Procedure For Identification And Recording Of High-Risk Facilities Resolution No. 956 of the Cabinet of Ministers of Ukraine of 14.07.2002 "On Identification And Declaring Of High-Risk Facilities Safety".
Covered Paragraph 3 — nuclear installations; Paragraph 13 — construction of railways and structures; Paragraph 21 — automobile refuelling stations.	List Of Activities And Facilities Of Increased Ecological Hazard. Resolution No. 554 of the Cabinet of Ministers of Ukraine of 27.07.2995 "On The List Of Activities And Facilities Of Increased Ecological Hazard".

Facility Covered (Not Covered) By RI	RI Title
Covered Paragraph 1 — equipment associated with the use, manufacture, processing, storage, recycling or disposal of hazardous and harmful substances; Paragraph 14 — electrical equipment intended for use (application) in hazardous areas; Paragraph 19 — cranes and lifting machines, elevators, escalators, moving walks, cable cars, ski lifts, in particular used in construction, and funiculars.	List Of Machines, Facilities, Mechanisms And Equipment Of High-Risk. Resolution No. 1107 of the Cabinet of Ministers of Ukraine of 26.10.2011 “On Approval Of Procedure For Issue Of Permits For High-Hazard Works And For Operation Of (Use) Of Machines, Mechanisms, And Equipment Of High Risk”.
Covered State enterprise NAEK Energoatom; State Specialized Enterprise “Chernobyl Nuclear Power Plant”	List of Highly Hazardous Enterprises-debtors, the termination of which requires implementation of special measures to prevent possible harm to the life and health of citizens, property, structures, and the environment. Resolution No. 339 of the Cabinet of Ministers of Ukraine of 15.05.2013 “On Implementation of Article 85 Of the Law of Ukraine ‘On Rehabilitation of Debts’ Solvency or Recognition as Insolvent’”
Covered Exclusion zone and Compulsory resettlement zone, including “Shelter” facility and other potentially hazardous facilities of the specialized enterprises located in these zones	List of facilities and separate territories subject to continuous and compulsory servicing on a contractual basis by the state emergency and rescue services. Resolution No. 1214 of the Cabinet of Ministers of Ukraine of 04.08.2000 “On Approval of Separate Territories Subject to Continuous and Compulsory Servicing on a Contractual Basis by the State Emergency and Rescue Services”

13.2.9 Conclusion On The Results Of Identification Of PHFs

According to the results of identification, the CSFSF is a potentially hazardous facility as defined by Paragraph 17 of Methods Of Identification Of Potentially Hazardous Facilities [77]. The maximum level of emergency in accordance with the Procedure For Classification Of Emergency Situations By Levels [86] is defined as “national”. The facility is subject to registration in the State Register Of Potentially Hazardous Facilities and the State Register Of Ionizing Radiation Sources.

13.2.10 Identification Of The Facility Under Design In Terms Of High Hazard

The facility, identified as potentially hazardous pursuant to Paragraph 1 of Procedure For Identification And Registration Of High-Risk Factors [78], is subject to identification for the purpose of its classification as the facility of high hazard.

At the same time, on the basis of Paragraph 1 of Procedure For Identification And Registration Of High-Risk Factors [78]б the PHF is subject to identified only in relation to its components containing hazardous substances listed in the Annexes 1 and 2 to Regulation on Threshold Masses of Hazardous Substances for the Identification of High Risk [78], and can not be identified as PHF on the condition of presence of RASs.

13.2.11 List Of Potentially Hazardous Facilities With Hazardous Substances, Isolated For Identification

For identification of the facilities under design in terms of hazard, the following objects (sites) with the presence of hazardous substances, as defined in Annexes 1 and 2 to Regulation on Threshold Masses of Hazardous Substances for the Identification of High Risk [78], are listed in Table 13.9.

The classification of hazardous substances under certain categories in terms of types of possible accidents is based on the classification set out in paragraphs 1 and 2 to Regulation on Threshold Masses of Hazardous Substances for the Identification of High Risk [78].

Table 13.9 — **List Of Potentially Hazardous Facilities With Hazardous Substances, Isolated For Identification Purposes**

PHF Name, Isolated For Identification, And Its Composition	Location of PHF	Name, Weight Of Hazardous Substance Or Group Of Hazardous Substances Used In The Facility	Name Or Category Of Hazardous Substance Or Group Of Hazardous Substances Used For Facility Identification	Identification Results (Belonging Of The HRF To Some Hazard Class)
Filling station	CSFSF site	Diesel fuel — 7.31 t	Category 2 (GZh), Groups 1 and 2 (explosion, fire)	Non classified as HRF*
Garage (warehouse)	CSFSF site	Motor oil — 0.03 t*	Category 2 (GZh), Group 2 (fire)	Non classified as HRF*

PHF Name, Isolated For Identification, And Its Composition	Location of PHF	Name, Weight Of Hazardous Substance Or Group Of Hazardous Substances Used In The Facility	Name Or Category Of Hazardous Substance Or Group Of Hazardous Substances Used For Facility Identification	Identification Results (Belonging Of The HRF To Some Hazard Class)
Electrical equipment building (diesel power plant premises)	CSFSF site	Diesel fuel — 0.75 t, motor oil — 0.04 t. Total — 0.79 t.	Category 2, (GZh) Groups 1 and 2 (explosion, fire)	Non classified as HRF*
* — for substantiation see Section 13.2.12.				

Other potentially hazardous facilities of high risk, except for the above, are not established.

13.2.12 Mass of Hazardous Substances Located At PHFs

For each potentially hazardous facility specified in Table 13.9, each production site, shop, unit, appliance being part of it, the hazardous substances have been identified wit determination of weight of each and the total weight. The data is set out in Table 13.10.

Table 13.10 — **List Of Hazardous Substances, Their Amounts And Hazard Categories**

PHF Name	Description of production (sites, installations, apparatuses, etc.) as parts of PHF	Hazardous substance name and weight, t	Weight of individual hazardous substance and mass of hazardous substances of each category to which it can be attributed according to the standards as to threshold weights, t										
			Separate substance	1	2	3	4	5	6	7	8	9	10
Filling station	Underground tanks (2x5 m^3)	Diesel fuel — 7.31 t	-	-	7.31	-	-	-	-	-	-	-	-
Garage (warehouse)	Canisters with motor oils (6x5 l)	Motor oil — 0.03	-	-	0.03	-	-	-	-	-	-	-	-
Building for electrical engineering devices (DPP)	Service tank (839 l)	Diesel fuel — 0.75	-	-	0.75	-	-	-	-	-	-	-	-
	Oil system (26.4 l)	Motor oil — 0.04	-	-	0.04	-	-	-	-	-	-	-	-

PHF Name	Description of production (sites, installations, apparatuses, etc.) as parts of PHF	Hazardous substance name and weight, t	Weight of individual hazardous substance and mass of hazardous substances of each category to which it can be attributed according to the standards as to threshold weights, t										
			Separate substance	1	2	3	4	5	6	7	8	9	10
TOTAL			-	-	8.13	-	-	-	-	-	-	-	-

In accordance with Art. 1 of the Law of Ukraine “On Hazardous Facilities” [75] and paragraph 4 of the Procedure For The Identification And Recording Of High-Risk Facilities [78], the PHF belongs to HRF of the corresponding class, if the value of total mass of hazardous substance or several substances used, produced, processed, stored or transported is equal to or exceeds the standard threshold mass.

Based on the fact that the mass of individual hazardous substances and their total mass is below the threshold established for hazardous substances, i.e. the facility actually handles 8.13 tonnes of hazardous substances (flammable liquids) while the minimum threshold value for the Class 2 HRF is 5,000 tonnes (Annex 2 to Procedure For The Identification And Recording Of High-Risk Facilities [78], Category 2), in accordance with paragraph 4 of Procedure For The Identification And Recording Of High-Risk Facilities [78], the identified potentially dangerous facility is not classified as of high risk.

13.2.9 Conclusion On The Results Of Identification Of HRFs

According to the results of identification, the facility under does not belong to the sites of increased danger and is not subject to registration in the State Register Of High-Risk Facilities and declaring of safety of high-risk facility.

14. ENVIRONMENTAL IMPACT ASSESSMENT

The state policy of Ukraine, as provided for in the Constitution of Ukraine, [87] is aimed to ensure the environmental safety and maintenance of the ecological balance on the territory of Ukraine.

For this purpose, Ukraine carries out, on its territory, ecological policy aimed at maintaining safe environment for the living and inanimate nature, protection of life and health of the population from the negative effects caused by the environmental pollution, to achieve a harmonious interaction between the society and the nature, protection, rational use and restoration of the natural resources [87, 89].

CSFSF designing process shall be performed in three stages. Assessment of the CSFSF environmental impact was carried out at the first stage of the design, as part of the investment feasibility study. The EIA results were approved by Decree of the Cabinet of Ministers of Ukraine No. 131-r of 04 February 2009 on the basis of the comprehensive conclusion (positive) issued by Ukrderzhbudekspertyza SE on 26 August 2008 under
№84 / 54 / 288o.

EIA as part of the CSFSF project (second approvable design stage) was carried out with consideration of:

- refinement of design solutions of the technology provider;
- raw data, regulated by the Law of Ukraine on Regulation of the Town Planning Activity;
- requirements of the normative-legal acts in the field of environmental protection, which became effective following the provision (26.08.2008) of the comprehensive conclusion of the state examination of the CSFSF investment feasibility study [115].

The presented section of the EIA is based on the requirements of DBN A.2.2-1-2003 [90], the Ukrainian environmental and sanitary legislation, as well as on some specific conditions of the design object in the exclusion zone, and the unconditional (obligatory) resettlement — the exclusion and compulsory resettlement zone [97].

The materials of Environmental Impact Assessment are available in Volumes 12.1, “Environmental Impact Assessment. Part 1. EIA Materials”, and 12.2, “Environmental Impact Assessment. Part 2. Annexes”.

14.1 Description Of Activities

The Central Spent Fuel Storage Facility (CSFSF) is a nuclear facility of national importance.

The CSFSF is intended to store spent nuclear fuel (SNF) from VVER reactors installed in units Rivne 1 to 4, Khmelnitsky 1 to 2, Yuzhnoukrainska 1 to 3 by means of the gradual increase in the capacity, equipping with the systems providing for preparation, for storage, transportation and safe storage.

The CSFSF uses the technology of “dry” storage of spent nuclear fuel in special casks, namely:

- the storage of spent nuclear fuel to be used is a surface “dry” storage with double-barrier insulation system;
- CSFSF lifetime — 100 years;
- CSFSF capacity — 16529 SFAs, including: 12,010 pcs of VVER-1000 SFAs and 4,519 pcs of VVER-400.

The CSFSF is based on the technology by Holtec International (hereinafter — Holtec).
The system developed by Holtec comprises the following components:

- MPC — multi-purpose cask;
- HI-STAR 190 UA (hereinafter—HI-STAR)—transportation cask;
- HI-STORM 190 UA (hereinafter—HI-STORM)—storage cask;
- HI-TRAC 190 UA (hereinafter—HI-TRAC)—transfer cask;
- cask transfer facility (CTF);
- cask transfer device (CTD);
- vertical cask transporter (VCT);
- a rail car transporter for the HI-STAR.

14.2 Service Life

The planned service life is up 100 years, including the active period (accumulation and storage of casks with SFAs) of up to 50 years and the subsequent passive period (storage of casks with SFAs).

14.3 Socio And Economic Need For The Proposed Activity

The social and economic need for the planned activity is the assurance of sustained long-term operation of Ukraine's nuclear power plants.

The CSFSF construction will make it possible to make use of own spent nuclear fuel storage facilities, and avoid dependence from spent nuclear fuel storage services provided abroad.

14.4 Need For Resources During Construction And Operation

14.4.1 Land Resources

In order to implement the planned activities, the land plot of 18.2 hectares was allocated for permanent use. The intended purpose of the land plot, in accordance with the Classifier [99], is "1.10.5, Construction of the Central Spent Fuel Storage Facility for the VVER Reactors of Nuclear Power Plants of Ukraine."

14.4.2 Primary Resources

Basic structures and materials, precast concrete and reinforced concrete elements, metal structures, concrete, rubble, sand, bricks, concrete blocks, cement and other materials will be supplied from specialized enterprises in Kiev and Zhitomir regions of Ukraine.

14.4.3 Energy Resources

The CSFSF uses one type of fuel — diesel fuel.

Fuel consumption on the site during construction of the CSFSF is 94.254 t/year.

The total annual fuel consumption by the CSFSF site during the operation is 25 m^3/year.

The annual energy consumption during construction of the CSFSF is 1671.06 thousand kWh/year.

The annual energy consumption during operation of the CSFSF is 4,750.98 thousand MWh/year.

14.4.4 Water Resources

The annual water consumption during construction of the CSFSF is 7,233 m^3/year.
The annual water consumption during operation of the CSFSF is 3,309.5 m^3/year.

14.4.5 Human Resources

Construction will be carried out by the Ukrainian construction and assembly companies. The maximum demand for human resources 430 people per day, including the biggest shift of 280 people (70% of the total staffing requirements).

The number of the CSFSF staff is preliminarily assessed at 161 people of permanent staff and 95 people in the maximum shift.

Beside the personnel of the CSFSF, according to the National Guard of Ukraine, there will be up to 58 servicemen of the National Guard in ordinary daily duty, and up to 68 servicemen in strengthened duty.

14.4.6 Transport

The transport resources available during construction and operation are as follows:

- rail transport (general-purpose and specialized transport) — a network of public and on-site railway tracks;
- road transport (civil and passenger transport) — existing roads.

14.5 Process Waste and Opportunity for Their Reuse, Recycling, Decontamination or Safe Disposal

The process waste and the opportunity for their reuse, recycling, utilization, decontamination or safe disposal: non-radioactive waste will be disposed of in public dumps, radioactive waste will be collected, stored temporarily and sent to the specialized facilities for recycling/disposal.

14.6 Environmental And Other Constraints On The Proposed Activity

The ecological and sanitary-epidemiological restrictions applied to the construction and operation of the CSFSF are aimed at the implementation of the proposed activity and operation without deterioration of the existing environmental performance around the CSFSF, taking into account the compliance with the limits of radiation-hygienic parameters established by DGN 6.6.1-6.5.001-98 [101] and DGN 6.6.1-6.5.061-2000 [102].

Also, the environmental and sanitary-epidemiological limits are determined by the presence of control limits, threshold levels and levels of action as to the radioactive contamination of the sites for the exclusion and compulsory resettlement zone [112].

Moreover, the environmental and sanitary-epidemiological limits are determined by the presence of the sanitary protection zone around the designed site, according to DSP-173-96 [100].

The size of the sanitary protection zone and a surveillance zone defined in CSFSF TEOI CSFSF [104].

- the sanitary protection zone — within 100 m from the border of the site, taking into account the geometry of the CSFSF site;
- the CSFSF control zone — within 600 m from the storage site.

As part of the fire safety design for object, the following restrictions are established:

- the buildings and structures are located on the site of the enterprise with regard for the minimum required distances (fire breaks) between them, as established by SNIP II-89-80* [50].
- the limitations concerning the fire resistance of the buildings and structures (degree of fire resistance) stipulated by the fire resistance classes of the building structures established by DBN V.1.1-7-2002 [17].
- the number of storeys and the floor areas of buildings within the fire compartments are limited by the requirements of SNiP 2.09.02-85 [118], SNiP 2.11.01-85 [119], DBN V.2.2-28:2010 [120].
- the restrictions as to the equipment of the enterprise territory, the buildings and structures, the systems, indoor and outdoor fire water supply, fire-protection systems (fire alarm, automatic fire suppression, fire warning and evacuation, smoke detection, centralized fire monitoring, lightning protection), as well as the implementation of the measures in fire protection of the engineering systems not related to the fire-protection system (heating and ventilation systems, electrical systems, emergency lighting systems, etc.) are set by DBN V.2.5-56:2014 [22], DBN V.2.5-64:2012 [46], DBN V.2.5-67:2013 [121], DBN V.2.5-74:2013 [20], DBN V.2.5-28:2006 [21], DSTU B V.2.5-38:2008 [26], NPAOP 40.1-1.32-01 [122], PUE [16] and others.
- during operation of the enterprise, the restrictions are applied in terms of performance of a set of organizational and technical measures to ensure fire safety conditions and in accordance with the requirements of NAPB A.01.001-2014 [27].

Fire safety restrictions are described in Volume 9 (571402.201.009-PB).

The planning terms and restrictions are provided in Appendix D, Volume 12.2. Environmental Impact Assessment. Part 2. Annexes.

14.7 Public Participation

For the purpose of informing the public about the proposed activity, taking into account the requirements of the Convention On Access To The Information, Public Participation In Decision-Making And Access To Justice In The Environmental Matters" [58] ratified by Ukraine on July 06, 1999 [59], the following actions were take at the feasibility study stage:

- publication of the Statement of Intent (25.01.2007);
- holding of a public consultation process on the construction of the central storage facility for nuclear fuel from the VVER nuclear power plants of Ukraine (after 06.02.2008);
- holding of a round table in Slavutych on the construction of the CSFSF (28.02.2008);
- holding of a round table in Ivankiv on the construction of the CSFSF (01.03.2008);

- public hearings on the planned activity in Slavutych, Kyiv Region (22.03.2008);

publication of the Environmental Impact Statement (07.03.2007).

Following the principles of the environmental policy of National Nuclear Energy Generating Company "Energoatom" and in accordance with the requirements of the legislation of Ukraine, the information on the proposed activity is kept up to date on the website of the National Nuclear Energy Generating Company "Energoatom". The links to the materials on the public relations under the CSFSF project are posted on the official website of the National Nuclear Energy Generating Company "Energoatom" as shown in Table 14.1.

Table 14.1 — **Links To The Materials On Public Relations Under The CSFSF Project**

Description	**Electronic address (URL) of the remote resource**
Media about CSFSF	http://www.energoatom.kiev.ua/ru/actvts/stroitelstvo/cssnf/media/
Materials for the public	http://www.energoatom.kiev.ua/ru/actvts/stroitelstvo/cssnf/press/
Official documents	http://www.energoatom.kiev.ua/ru/actvts/stroitelstvo/cssnf/official/

For the purpose of informing the public about the planned activity, the Project stage involves the following actions:

- publication of the Environmental Impact Statement;
- information update on the website of National Nuclear Energy Generating Company "Energoatom".

14.8 Assessment Of Impact Of Construction, Operation And Accidents At The CSFSF On The Territory Of The Neighboring States

On stage IFS stage [104], in accordance with the Convention on Environmental Impact Assessment in a Transboundary Context [115], ratified by Ukraine on 19 March 1999 [117], the activities in the neighbouring states in raising awareness about the possible impact of the CSFSF were held.

14.9 Obligations In Relation To Environmental Safety

General designer — Public Joint Stock Company "Kyiv Research and Design Institute 'Energoproect'"(PJSC KIEP) will supervise the compliance of the activities with the design solutions.

Operating organization — Energoatom National Nuclear Energy Generating Company — will ensure:

- safe operation in accordance with the regulations, operating instructions, and technological regulations valid in Ukraine;
- appropriate management structure, and maintenance personnel qualification;
- continuous monitoring during operation, ensuring the implementation of environmental safety measures.

14.10 Results Of The Environmental Impact Assessment Of The Planned Activity

No thermal pollution or evaporation is expected during operation of the CSFSF. The CSFSF operation does not affect the sunlight exposure intensity, temperature, wind velocity, humidity, atmospheric inversions, fog duration, and other climate features. With that being said, there is no impact on the climate and microclimate.

Under normal conditions of work and in case of accidents, additional radiation exposure is extremely insignificant.

Due to a sufficient distance from the site to the territories with controlled levels of the living environment, the pollutant emissions will not have negative impact on health and lifestyle of the population of the adjacent areas. Analysis of the results of the calculations of surface pollutant concentrations shows that implementation of this project is performed with adherence to the respective sanitary and hygienic standards for each pollutant considered.

In terms of air pollution, the operation of the facility is permissible.

The acoustic effects of the operation of the facility will be permanent and will accompany the activities on the site during the whole operation period. Analysis of the obtained results of the calculations of acoustic effects show that the noise discomfort zone of the technological equipment does not exceed the boundaries of the SPZ and will not affect the formation of further sound field.

Operation of the facility, in terms of expected noise, is acceptable.

The impact of electric and electromagnetic fields during operation of the facility will be permanent during the whole operation period. The impact of electrical equipment (transformers, generators, electrical drives, diesel generator power units) is absent. The impact of radio antennas is permissible. Due to a quite large distance from the facility to the territories with controlled quality of the living environment, the site operation will not result in exceeding the sanitary and hygienic standards. Electromagnetic field generated around the radio facilities (radio antennas) is safe for the human health.

Operation of the facility, in terms of electric and electromagnetic impact, is acceptable.

There are no active karst and karst-suffosion processes, as well as landslides and shifts that could lead to disruption of normal operation of the facility.

Implementation of this project gives no direct discharges into the aquatic environment.

Results of the environmental impact assessment are provided in the project with consideration of refinement of the CSFSF technology, equipment and infrastructure and with consideration of requirements of normative-legal acts in the field of environmental protection, and confirm the EIA results represented in the investment feasibility study. Environmental impact of the planned activity is acceptable.

Radiation contamination risk assessment

- the impact on the environment does not exceed the current state of the environment, does not exceed the exposure standards valid for the E&CRZ, and can be considered acceptable (according to the reference levels)

Assessment of the human health risk from air pollution by chemicals

- the risk of non-carcinogenic effects is extremely low, the likelihood of adverse effects increases pro rate to the increase of the hazard coefficients for certain substances;

- the risk of carcinogenic effects is conditionally acceptable;
- the social risk of the planned activities is conditionally acceptable.

Analysis of the results obtained from the performed calculations and assessment of the CSFSF radiation impact shows that the risk of the facility for the environment and public health is acceptable.

Analysis of the results obtained from the performed calculations during assessment of the risk of the air pollution with chemical contaminants to the public health shows that the risks of the planned activity impact on the environment are assumed acceptable.

Upon the assessment of the risks, implementation of this project is not subject to any restriction.

The analysis of the design values of radiation impact on the components of the environment in the border areas of the Republic of Belarus as a result of construction, normal operation and accidents at the CSFSF, carried out and the design stage, proves the conclusions state in the IFS as to the transboundary impact of the CSFSF.

According to the results of analysis, the environmental impact of the planned facility during construction and operation is considered acceptable.

The materials of environmental impact assessment are available in Volumes 12.1, “Environmental Impact Assessment. Part 12.1. EIA Materials”, and 12.2, “Environmental Impact Assessment. Part 1. Materials 12.2 EIA and environmental impact assessment. Part 2. Annexes.”

15 ASSESSMENT OF SAVINGS FROM IMPLEMENTATION OF ENERGY-EFFICIENCY MEASURES

An assessment of efficiency of the measures to save energy has been carried out in conformity with DBN B.2.6-31:2006 [44] State Building Regulation.

In order to determine whether the existing walls and coverings meet the requirements of DBN B.2.6-31:2006 [44], thermotechnical calculations of enclosing structures have been conducted for the buildings as follows:

- acceptance building;
- administrative building (CD facility);
- maintenance building with MPC storage room;
- security facilities complex;
- guard building (CD facility);
- checkpoint 1;
- checkpoint 2;
- electrical equipment building;
- fire pump station;
- garage.

Design of heating, ventilation and air conditioning systems for CSFSF construction buildings includes the measures that, when meeting quality and operational requirements, will contribute to an efficient use of thermal energy and minimize heat losses to the environment.

15.1 Source Data

Design parameters of outside air for heating and ventilation systems have been assumed as per DSTU-H B B.1.1-27:2010 State Standard “Building Climatology” [106]:

- temperature of the cold period for calculating heating and ventilation systems is minus 22^{o}C;
- temperature of the warm period for calculating ventilation systems is minus +23^{o}C;
- temperature of the cold period of year for calculating air conditioning systems is +28^{o}C;
- average annual relative humidity is 74%.

15.2 Thermotechnical Calculation of Enclosing Structures for Offuice Building (CD Facility), Guard Building (CD Facility), Checkpoint 1 and Checkpoint 2

As required by Item 2.1 of DBN B.2.6-31:2006 [44], it is mandatory for enclosing structures that the following condition is met:

$$R_{\Sigma red} \geq R_{qmin} \qquad (15.1)$$

where $R_{\Sigma red}$ is a reduced resistance to heat transfer of the enclosing structure, m^2.K/W;

R_{qmin} is a minimum allowable resistance to heat transfer of the enclosing structure, m^2.K/W.

As required by Item 2.2 of DBN B.2.6-31:2006 [44], the minimum allowable value of resistance to heat transfer of the enclosing structure R_{qmin} , m^2.K/W, for civil buildings should be established according to Table 1 of DBN B.2.6-31:2006 [44] depending on:

- the temperature in the facility operation area as per Appendix B [44];
- heat-to-humidity conditions as per Appendix G [44].

As follows from Appendix B to DBN B.2.6-31:2006 [44], the construction object is located in the operation temperature area I.

As follows from Appendix G to DBN B.2.6-31:2006 [44], at the preset temperature of inside air in the cold period (+18^{o}C), a normal heat-to-humidity condition for the premises is designed with a relative humidity of inside air not exceeding 60%.

Under normal heat-to-humidity conditions in keeping with Appendix K [44], we assume "B" conditions for operation of material in the enclosing structures.

For the wall cladding of buildings in the operation temperature area I, a minimum allowable resistance to heat transfer must be:

R_{qmin} = 3.3 (m^2 x K)/W (Table 1, [44]).

A minimum thickness δ (m) of thermal covering was derived from the boundary condition to meet the requirement of (1) $R_{\Sigma red} \geq R_{qmin,}$ i.e. for the condition of:

$$(R_{\Sigma red}=R_{qmin}) \qquad (15.2)$$

As the condition (1) is verified, the reduced resistance to heat transfer of the enclosing structure, $R_{\Sigma red}$ m^2.K/W, is calculated as per Appendix I (Item 2.10 [44]) by (I.1):

$$R_{\Sigma np} = \frac{1}{\alpha_в} + \sum_{1}^{i} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_з}, \qquad (15.3)$$

where α_B = 8.7 W/(m^2 x K) is a heat transfer coefficient, W/(m^2.K), of the inner surface of enclosing structure ([44], Appendix E);

α_3 = 23 W/(m^2 x K) is a heat transfer coefficient for winter conditions, W/(m^2 x K), of the outer surface of enclosing structure ([44], Appendix E);

δ_i is the thickness of the i-th layer of the structure, m;

λ_i is the heat conductivity, W/(m.K), of the i-th layer of the structure under the rated duty, according to Item 2.11 and Appendix Л [44].

15.2.1 Office Building (CD Facility)

<u>Wall cladding</u> is composed as follows:

- ventilated façade from 4 mm thick composite panels (neglected for the calculation);
- IZOVAT-80 mineral wool slabs, density of 80 kg/m^3, thickness is to be defined by design, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.041 W/(m.K);
- walls are made from foam concrete blocks D700 600x400x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 400 mm, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Table 1 of DBN B.2.6-31:2006 [44]).

For the wall cladding of buildings in the operational temperature area I, a minimum allowable resistance to heat transfer must be:

R_{qmin} = 3.3 (m^2 x K)/W (Table 1, DBN B.2.6-31:2006 [44]).

For a multi-layer structure, resistance to heat transfer, R_{const} (m^2.K/W), is calculated by (5) DBN B.2.6-31:2006 [44]:

$$R_{конст.} = \sum_{1}^{3} \frac{\delta_i}{\lambda_i} = \frac{\delta}{0,041} + \frac{0,4}{0,27}$$

$$R_{конст.} = \frac{\delta}{0,041} + 1,481$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,481 + \frac{\delta}{0,041}\right) + \frac{1}{23} = 0,115 + 1,481 + \frac{\delta}{0,041} + 0,043 = 1,639 + \frac{\delta}{0,041}$$

A minimum thickness, δ (m), of the thermal covering is found from the boundary condition:

($R_{\Sigma red}=R_{qmin}$)

($R_{\Sigma red}$ = 1.639 + δ/0.041) = (R_{qmin}= 3.3)

1.639 + δ/0.041 = 3.3

δ/0.041 = 3.3 – 1.639

δ = (3.3 – 1.639) x 0.041 = 0.0681 m

<u>Assume δ = 100 mm considering slab fabrication conditions.</u>

The requirements of Item 2.1 DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm are met:

[$R_{\Sigma red}$ = 4.078 m^2.K/W] ≥ [R_{qmin} = 3.3 m^2.K/W].

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-80 mineral wool slabs (density of 80 kg/m^3).

<u>Basement</u> is made of the following materials:

- 10 mm thick ceramic granite tile (neglected for the calculation);
- Ceresit CT 17 bonding aggregate (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness being defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- walls made from foam concrete blocks D700 600x400x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 300 mm, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table Л.1 [44]).

For the wall cladding of buildings in the operational temperature area I, a minimum allowable resistance to heat transfer must be:

R_{qmin} = 3.3 (m^2 x K)/W (Table 1, DBN B.2.6-31:2006 [44]).

For a multi-layer structure, resistance to heat transfer, R_{const} (m^2.K/W), is found by:

$$R_{конст.} = \sum_{1}^{3} \frac{\delta_i}{\lambda_i} = \frac{\delta}{0,045} + \frac{0,4}{0,27}$$

$$R_{конст.} = \frac{\delta}{0,045} + 1,481$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ ($m^2.K/W$), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,481 + \frac{\delta}{0,045}\right) + \frac{1}{23} = 0,115 + 1,481 + \frac{\delta}{0,045} + 0,043 = 1,639 + \frac{\delta}{0,045}$$

A minimum thickness, δ (m), of the thermal covering is found from the boundary condition:

$(R_{\Sigma red}=R_{qmin})$

$(R_{\Sigma red} = 1.639 + \delta/0.045) = (R_{qmin}= 3.3)$

$1.639 + \delta/0.045 = 3.3$

$\delta/0.045 = 3.3 – 1.639$

$\delta = (3.3 – 1.639) \times 0.045 = 0.075$ m

Assume δ = 100 mm considering slab fabrication conditions.

The requirements of Item 2.1 DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm are met:

$[R_{\Sigma red} = 3.861\ m^2.K/W] \geq [R_{qmin} = 3.3\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

Roof covering is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane mounted mechanically (neglected for the calculation);
- 50 mm thick insulant – 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, thickness to be determined by the calculation, density of 110 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs, density of 110 kg/m^3, average thickness of 100 mm (neglected for the calculation);
- vapor seal – 200 μ thick polyethylene film (neglected for the calculation);
- 200 mm thick reinforced concrete plates, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K).

For the roof covering of buildings in the operational temperature area I, a minimum allowable resistance to heat transfer must be:

R_{qmin} = 4.95 (m^2 x K)/W (Table 1, DBN B.2.6-31:2006 [44]).

For a multi-layer structure, resistance to heat transfer, R_{const} ($m^2.K/W$), is found by (5) DBN B.2.6-31:2006 [44]:

$$R_{конст.} = \sum_{1}^{3} \frac{\delta_i}{\lambda_i} = \frac{0,05}{0,046} + \frac{\delta}{0,042} + \frac{0,2}{2,04}$$

$$R_{конст.} = \frac{\delta}{0,042} + 1,184$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ ($m^2.K/W$), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,184 + \frac{\delta}{0,042}\right) + \frac{1}{23} = 0,115 + 1,184 + \frac{\delta}{0,042} + 0,043 = 1,342 + \frac{\delta}{0,042}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

$(R_{\Sigma red}=R_{qmin})$

$(R_{\Sigma red} = 1.342 + \delta/0.042) = (R_{qmin}= 4.95)$

$1.342 + \delta/0.042 = 4.95$

$\delta/0.042 = 4.95 – 1.342$

$\delta = (4.95 – 1.342) \times 0.042 = 0.151$ m

<u>Assume δ = 200 mm considering slab fabrication conditions.</u>

The requirements of Item 2.1 DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 200 mm (0.2 m) are met:

$[R_{\Sigma red} = 6.1 \text{ m}^2.\text{K/W}] \geq [R_{qmin} = 4.95 \text{ m}^2.\text{K/W}]$.

The accepted thickness of the heat-insulation layer is 200 mm (0.2 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

Thermotechnical calculations for enclosing structures of the guard (CD facility), checkpoint 1 and checkpoint 2 buildings have been carried out in a similar manner. Results of the calculations are given in Table 15.1.

15.2.2 Guardhouse (CD Facility)

<u>Wall cladding</u> is made from the materials as follow:

- ventilated façade from 4 mm thick composite panels (neglected for the calculation);
- IZOVAT-80 mineral wool slabs, density of 80 kg/m^3, thickness is to be defined by design, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.041 W/(m.K);
- walls are made from foam concrete blocks D700 600x300x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 400 mm, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Item 56 of Table Л.1 of DBN B.2.6-31:2006 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

$[R_{\Sigma red} = 3.708 \text{ m}^2.\text{K/W}] \geq [R_{qmin} = 3.3 \text{ m}^2.\text{K/W}]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-80 mineral wool slabs (density of 80 kg/m^3).

<u>Basement</u> is made of the following materials:

- 10 mm thick façade ceramic granite tile (neglected for the calculation);
- Ceresit CT 17 bonding aggregate (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);

- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- walls made from foam concrete blocks D700 600x300x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 300 mm, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table Л of DBN B.2.6-31:2006 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 of DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

$[R_{\Sigma red} = 3.491\ m^2.K/W] \geq [R_{qmin} = 3.3\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

<u>Roof covering</u> is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs, density of 110 kg/m^3, average thickness of 100 mm (neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- 200 mm thick reinforced concrete plates, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 200 mm.

The requirements of Item 2.1 of DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 200 mm (0.2 m) are met:

$[R_{\Sigma red} = 5.88\ m^2.K/W] \geq [R_{qmin} = 4.95\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 200 mm (0.2 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.2.3 Checkpoint 1

<u>Wall cladding</u> is made from the materials as follow:

- ventilated façade (neglected for the calculation);
- IZOVAT-80 mineral wool slabs, density of 80 kg/m^3, thickness is to be defined by design, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.041 W/(m.K);

- walls from foam concrete blocks D700 600x300x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 350 mm, an estimated heat transfer coefficient for operational conditions B, $λ_B$, is 0.27 W/(m.K) (Item 56 of Table Л.1 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

$[R_{\Sigma red} = 3.893\ m^2.K/W] \geq [R_{qmin} = 3.3\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-80 mineral wool slabs (density of 80 kg/m^3).

Basement is made of the following materials:

- 10 mm thick façade ceramic granite tile RAL 7004 (neglected for the calculation);
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B ($λB$ = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- walls from foam concrete blocks D700 600x300x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 350 mm, an estimated heat transfer coefficient for operational conditions B is $λ_B$ = 0.27 W/(m.K) (Item 56 of Table Л.1 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 of DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

$[R_{\Sigma red} = 3.491\ m^2.K/W] \geq [R_{qmin} = 3.3\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

Roof covering is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is $λ_B$ = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is $λ_B$ = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs, density of 110 kg/m^3, average thickness of 100 mm (neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);

- 200 mm thick reinforced concrete plates, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 200 mm.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 200 mm (0.2 m) are met:

[$R_{\Sigma red}$ = 5.88 m^2.K/W] ≥ [R_{qmin} = 4.95 m^2.K/W].

The accepted thickness of the heat-insulation layer is 200 mm (0.2 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.2.4 Checkpoint 1

Wall cladding is made from the materials as follow:

- ventilated façade (neglected for the calculation);
- IZOVAT-80 mineral wool slabs, density of 80 kg/m^3, thickness is to be defined by design, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.041 W/(m.K);
- walls from foam concrete blocks D700 600x300x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 350 mm, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Item 56 of Table Л.1 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

[$R_{\Sigma red}$ = 3.893 m^2.K/W] ≥ [R_{qmin} = 3.3 m^2.K/W].

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-80 mineral wool slabs (density of 80 kg/m^3).

Basement is made of the following materials:

- 10 mm thick façade ceramic granite tile RAL 7004 (neglected for the calculation);
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- 2 mm thick Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- walls from foam concrete blocks D700 600x350x300 DSTU B B.2.7.137:2008 [107], density of 630-740 kg/m^3, thickness of 350 mm, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table Л.1 [44]).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 100 mm.

The requirements of Item 2.1 of DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

[$R_{\Sigma red}$ = 3.491 m^2.K/W] ≥ [R_{qmin} = 3.3 m^2.K/W].

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

Roof covering is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC membrane mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- grade D400 light concrete on the slope, 20-150 mm thick, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.23 W/(m.K).
- 200 mm thick reinforced concrete plates, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K).

After the calculation has been carried out basing on the slab fabrication condition, we assume δ to be 200 mm.

The requirements of Item 2.1 of DBN B.2.6-31:2006 [44] regarding the mandatory compliance with the condition (1) with the designed thickness of the heat-insulation layer being 200 mm (0.2 m) are met:

$[R_{\Sigma red} = 5.97\ m^2.K/W] \geq [R_{qmin} = 4.95\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 200 mm (0.2 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.3 Thermotechnical Calculation of Enclosing Structures for Acceptance Building

The acceptance building consists of two structural blocks:

- Acceptance building (within axes 1-8, A-B): central block (a space for transport and service operations);
- Acceptance building (within axes 1-8, A-D): auxiliary block.

15.3.1 Thermotechnical Calculation of Enclosing Structures for Acceptance Building (within Axes 1-8, A-B)

As required by Item 2.1 of DBN B.2.6-31:2006 [44], it is mandatory for outer fences that the following condition is met:

$$R_{\Sigma red} \geq R_{qmin} \quad (15.1)$$

where $R_{\Sigma red}$ is a reduced resistance to heat transfer of the enclosing structure, m^2.K/W;

R_{qmin} is a minimum allowable resistance to heat transfer of the enclosing structure, m^2.K/W.

As required by Item 2.4 of DBN B.2.6-31:2006 [44], the minimum allowable value of resistance to heat transfer of the enclosing structure R_{qmin}, m^2.K/W, for production buildings should be established according to Table 2 of DBN B.2.6-31:2006 [44] depending on:

- the temperature in the facility operation area as per Appendix B [44];
- heat-to-humidity conditions as per Appendix G [44];
- thermal inertia of the enclosing structure D that is found by the formula (4) [44].

As follows from Appendix B [44], the construction object is located in the operation temperature area I.

As follows from Appendix G [44], at the given (≤12°C) temperature of inside air in the cold period (≤12°C), a normal heat-to-humidity condition for the premises is assigned with a relative humidity of inside air not exceeding 75%.

Under normal heat-to-humidity conditions in keeping with Appendix K [44], conditions "B" are assumed for operation of material in the enclosing structures.

The thermal inertia for the structure assumed using the formula (4) of DBN B.2.6-31:2006 [44] will be:

$$D = \sum_{i}^{7} R_i \cdot S_i$$

where R_i is a thermal resistance, $m^2.K/W$, of a layer in the multi-layer enclosing structure;

S_i is an estimated heat absorption coefficient for a separate layer of the enclosing structure given operating condition B, $W/(m^2.K)$, according to Appendix L [44].

For buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under a *normal* heat-to-humidity condition for premises where D>1.5 must be:

- R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44] for wall cladding;
- R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44] for basement;
- R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44] for roof covering.

A minimum thickness δ (m) of thermal covering was derived from the boundary condition to meet the requirement of (1) $R_{\Sigma red} \geq R_{qmin,}$ i.e. for the condition of:

($R_{\Sigma red} = R_{qmin}$)

As the condition (1) is verified, the reduced resistance to heat transfer of the enclosing structure, $R_{\Sigma red}$ $m^2.K/W$, is calculated as per Appendix I (Item 2.10 of DBN B.2.6-31:2006 [44]) by (I.1):

$$R_{\Sigma пр} = \frac{1}{\alpha_в} + \sum_{1}^{i} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_з},$$

where α_B = 8.7 W/(m^2 x K) is a heat transfer coefficient, $W/(m^2.K)$, of the inner surface of enclosing structure ([44], Appendix E);

α_3 = 23 W/(m^2 x K) is a heat transfer coefficient for winter conditions, W/(m^2 x K), of the outer surface of enclosing structure ([44], Appendix E);

δ_i is the thickness of the i-th layer of the structure, m;

λ_i is the heat conductivity, W/(m.K), of the i-th layer of the structure under the rated duty, according to Item 2.11 and Appendix Л [44].

Wall cladding is made from the materials as follow:

- corrugated sheet (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 $kg/m^{3)}$, thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.045 W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);

- 300 mm thick reinforced concrete wall, an estimated heat transfer coefficient for operational conditions B, λ_B, is 2.04 W/(m.K) (Item 81 of Table Л.1 of DBN B.2.6-31:2006 [44]).

The thermal inertia for the structure assumed using the formula (4) of DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{7} R_i \cdot S_i = \frac{0,3}{2,04} \cdot 18,95 = 2,79$$

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under a *normal* heat-to-humidity condition for premises where D>1.5 must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by (5) of DBN B.2.6-31:2006 [44]:

$$R_{конст} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{\delta}{0,045} + \frac{0,3}{2,04}$$

$$R_{конст.} = \frac{\delta}{0,045} + 0,147$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(0,147 + \frac{\delta}{0,045}\right) + \frac{1}{23} = 0,115 + 0,147 + \frac{\delta}{0,045} + 0,043 = 0,305 + \frac{\delta}{0,045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}$=R_{qmin})

($R_{\Sigma red}$ = 0.305 + δ/0.045) = (R_{qmin}= 1.7)

0.305 + δ/0.045 = 1.7

δ/0.045 = 1.7 – 1.305

δ = (1.7 – 0.305) x 0.045 = 0.062775 m

δ is accepted as 70 mm basing on the slab fabrication conditions.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 70 mm (0.07 m) are met:

[$R_{\Sigma red}$ = 1.861 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 70 mm (0.07 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

Roof covering is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1 layer - 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);

- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 200 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K) (Item 81, Table L.1 [44]).

The thermal inertia for the structure assumed using the formula (4) of DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{n} R_i \cdot S_i = \frac{0,04}{0,046} \cdot 0,77 + \frac{0,3}{2,04} \cdot 18,95 = 3,457$$

For the roof covering of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under a *normal* heat-to-humidity condition for premises where D>1.5 must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) of DBN B.2.6-31:2006 [44]:

$$R_{конст.} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{0,04}{0,046} + \frac{\delta}{0,042} + \frac{0,3}{2,04}$$

$$R_{конст.} = \frac{\delta}{0,042} + 1,016$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,016 + \frac{\delta}{0,042}\right) + \frac{1}{23} = 0,115 + 1,016 + \frac{\delta}{0,042} + 0,043 = 1,174 + \frac{\delta}{0,042}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}$=R_{qmin})

($R_{\Sigma red}$ = 1.174 + δ/0.042) = (R_{qmin}= 1.7)

1.174 + δ/0.042 = 1.7

δ/0.042 = 1.7 – 1.174

δ = (1.7 – 1.174) x 0.042 = 0.02209 m

δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1 [44] of DBN B.2.6-31:2006 regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.364 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.3.2 Thermotechnical Calculation of Enclosing Structures for Acceptance Building (within Axes 1-8, B-D)

Wall claddings (within axes 1-8, B-D) are made from the materials as follow:

- corrugated sheets (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.045 W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);
- 300 mm thick foam concrete wall, D700 600x300x300 DSTU B.2.7-137:2008, density of 630-740 kg/m^3, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Item 56 of Table L.1 [44]).

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance must be:

R_{qmin} = 3.3 (m^2 x K)/W (Table 1 [44]

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition to meet the requirement (1) ($R_{\Sigma red} \geq R_{qmin}$), i.e. for the condition:

($R_{\Sigma red}=R_{qmin}$)

To verify the condition (1), the reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found in accordance with Appendix I [44], Item 2.10, using the formula (I.1):

$$R_{\Sigma np} = \frac{1}{\alpha_в} + \sum_1^i \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_з},$$

where α_B = 8.7 W/(m^2 x K) is a heat transfer coefficient, W/(m^2.K), of the inner surface of enclosing structure ([44], Appendix E);

α_3 = 23 W/(m^2 x K) is a heat transfer coefficient for winter conditions, W/(m^2 x K), of the outer surface of enclosing structure ([44], Appendix E);

δ_i is the thickness of the i-th layer of the structure, m;

λ_i is the heat conductivity, W/(m.K), of the i-th layer of the structure under the rated duty, according to Item 2.11 and Appendix L [44].

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) [44]:

$$R_{констр.} = \sum_1^3 \frac{\delta_i}{\lambda_i} = \frac{\delta}{0{,}045} + \frac{0{,}3}{0{,}27}$$

$$R_{констр.} = \frac{\delta}{0{,}045} + 1{,}111$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma np} = \frac{1}{8{,}7} + \left(1{,}111 + \frac{\delta}{0{,}045}\right) + \frac{1}{23} = 0{,}115 + 1{,}111 + \frac{\delta}{0{,}045} + 0{,}043 = 1{,}269 + \frac{\delta}{0{,}045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}=R_{qmin}$)

($R_{\Sigma red}$ = 1.269 + δ/0.045) = (R_{qmin}= 3.3)

1.269 + δ/0.045 = 3.3

$\delta/0.045 = 3.3 – 1.269$

$\delta = (3.3 – 1.269) \times 0.045 = 0.0914$ m

<u>δ is accepted as 100 mm basing on the slab fabrication conditions.</u>

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 100 mm (0.1 m) are met:

$[R_{\Sigma red} = 3.491\ m^2.K/W] \geq [R_{qmin} = 3.3\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 100 mm (0.1 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

<u>Wall basement (within axes 1-8, B-D)</u> is made from the following materials:

- 10 mm thick façade ceramic granite tile, an estimated heat transfer coefficient for the operational conditions B (λB = 1.1 W/(m.K) (Item 80, Table L.1 [44];
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B is $\lambda_B = 0.27$ W/(m.K) (Item 56 of Table L, [44]).

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance must be:

$R_{qmin} = 3.3\ (m^2 \times K)/W$ (Table 1 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) [44]:

$$R_{констр.} = \sum_1^8 \frac{\delta_i}{\lambda_i} = \frac{\delta}{0,045} + \frac{0,3}{0,27}$$

$$R_{констр.} = \frac{\delta}{0,045} + 1,111$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,111 + \frac{\delta}{0,045}\right) + \frac{1}{23} = 0,115 + 1,111 + \frac{\delta}{0,045} + 0,043 = 1,269 + \frac{\delta}{0,045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

$(R_{\Sigma red}=R_{qmin})$

$R_{\Sigma red} = 1.269 + \delta/0.045) = (R_{qmin}= 3.3)$

$1.269 + \delta/0.045 = 3.3$

$\delta/0.045 = 3.3 – 1.269$

$\delta = (3.3 – 1.269) \times 0.045 = 0.0914$ m

<u>δ is accepted as 100 mm basing on the slab fabrication condition</u>s.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 100 mm (0.1 m) are met:
[$R_{\Sigma red}$ = 3.491 m^2.K/W] ≥ [R_{qmin} = 3.3 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

<u>Roof covering (within axes 1-8, B-D)</u> is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 300 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K) (Item 81, Table L.1 [44])

For the roof covering of buildings in the operational temperature area I, a minimum allowable heat transfer resistance must be:

R_{qmin} = 4.95 (m^2 x K)/W (Table 1 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) [44]:

$$R_{конст.} = \sum_{1}^{8} \frac{\delta_i}{\lambda_i} = \frac{0,04}{0,046} + \frac{\delta}{0,042} + \frac{0,2}{2,04}$$

$$R_{конст.} = \frac{\delta}{0,042} + 0,9676$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(0,9676 + \frac{\delta}{0,042}\right) + \frac{1}{23} = 0,115 + 0,9676 + \frac{\delta}{0,042} + 0,043 = 1,1256 + \frac{\delta}{0,042}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}$=R_{qmin})
($R_{\Sigma red}$ = 1.1256 + δ/0.042) = (R_{qmin}= 4.95)
1.1256 + δ/0.042 = 4.95
δ/0.042 = 4.95 – 1.1256
δ = (4.95 – 1.1256) x 0.042 = 0.161 m
<u>δ is accepted as 200 mm basing on the slab fabrication conditions</u>.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 200 mm (0.2 m) are met:

$[R_{\Sigma red} = 5.88\ m^2.K/W] \geq [R_{qmin} = 4.95\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 200 mm (0.2 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.4 Thermotechnical Calculation for Heated Portion of Maintenance Building with MPC Storage Room

As required by Item 2.1 of DBN B.2.6-31:2006 [44], it is mandatory for outside enclosing structures that the following condition is met:

$$R_{\Sigma red} \geq R_{qmin}$$

where $R_{\Sigma red}$ is a reduced resistance to heat transfer of the enclosing structure, $m^2.K/W$;

R_{qmin} is a minimum allowable resistance to heat transfer of the enclosing structure, $m^2.K/W$.

As required by Item 2.4 of DBN B.2.6-31:2006 [44], a minimum allowable value of resistance to heat transfer of the enclosing structure R_{qmin}, $m^2.K/W$, for production buildings should be established according to Table 2 of DBN B.2.6-31:2006 [44] depending on:

- the temperature in the facility operation area as per Appendix B [44];
- heat-to-humidity conditions as per Appendix G [44].
- thermal inertia of the enclosing structure D that is found by the formula (4) [44].

As follows from Appendix B [44], the construction object is located in the operation temperature area I.

As follows from Appendix G [44], at the given temperature of inside air in the cold period (+5°C), a normal heat-to-humidity condition is assigned for the space with a relative humidity of inside air not exceeding 75%.

Under normal heat-to-humidity conditions in keeping with Appendix K [44], we assume “B” conditions for operation of material in the enclosing structures.

Wall claddings are made from the materials as follow:

- corrugated sheets (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is $\lambda_B = 0.045$ W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);
- Wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Item 56 of Table L.1 [44]).

The thermal inertia for the structure assumed using the formula (4) [44] will roughly be:

$$D = \sum_{1}^{7} R_i \cdot S_i = \frac{0,3}{0,27} \cdot 3,98 = 4,42$$

where R_i is a thermal resistance, $m^2.K/W$, of a layer in the multi-layer enclosing structure;

S_i is an estimated heat absorption coefficient for a separate layer of the enclosing structure given operating condition B, $W/(m^2.K)$, according to Appendix L [44].

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under normal heat-to-humidity condition for premises where D>1.5) must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44]

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition to meet the requirement (1) ($R_{\Sigma red} \geq R_{qmin}$), i.e. for the condition:

($R_{\Sigma red} = R_{qmin}$)

To verify the condition (1), the reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found in accordance with Appendix I [44], Item 2.10, using the formula (I.1):

$$R_{\Sigma np} = \frac{1}{\alpha_{в}} + \sum_{1}^{i} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_{з}},$$

where α_B = 8.7 W/(m^2 x K) is a heat transfer coefficient, W/(m^2.K), of the inner surface of enclosing structure ([44], Appendix E);

α_3 = 23 W/(m^2 x K) is a heat transfer coefficient for winter conditions, W/(m^2 .K), of the outer surface of enclosing structure ([44], Appendix E);

δ_i is the thickness of the i-th layer of the structure, m;

λ_i is the heat conductivity, W/(m.K), of the i-th layer of the structure under the rated duty, according to Item 2.11 and Appendix L [44].

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) [44]:

$$R_{конст.} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{\delta}{0{,}045} + \frac{0{,}3}{0{,}27}$$

$$R_{конст.} = \frac{\delta}{0{,}045} + 1{,}111$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma np} = \frac{1}{8{,}7} + \left(1{,}111 + \frac{\delta}{0{,}045}\right) + \frac{1}{23} = 0{,}115 + 1{,}111 + \frac{\delta}{0{,}045} + 0{,}043 = 1{,}269 + \frac{\delta}{0{,}045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red} = R_{qmin}$)

($R_{\Sigma red}$ = 1.269 + δ/0.045) = (R_{qmin}= 1.7)

1.269 + δ/0.045 = 1.7

δ/0.045 = 1.7 – 1.269

δ = (1.7 – 1.269) x 0.045 = 0.019395 m

<u>Following the calculation, δ is accepted as 50 mm basing on the slab fabrication conditions.</u>

The requirements of Item 2.1, DBN B.2.6-31:2006 [44], regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.380 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

<u>Wall basement</u> is made from the following materials:

- 10 mm thick façade ceramic granite tile, an estimated heat transfer coefficient for the operational conditions B (λB = 1.1 W/(m.K) (Item 80, Table L.1 [44];
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);

- Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table L, [44]).

Following the calculation, δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.389 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

Roof covering is made from the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1 layer - 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 220 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K) (Item 81, Table L.1 [44])

After the calculation has been completed, δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1 [44] regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.326 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.5 Thermotechnical Calculations of Wall Claddings for Electrical Equipment Building, Fire Pump Station and Garage

As required by Item 2.1 of DBN B.2.6-31:2006 [44], it is mandatory for outside enclosing structures that the following condition is met:

$$R_{\Sigma red} \geq R_{qmin}$$

where $R_{\Sigma red}$ is a reduced resistance to heat transfer of the enclosing structure, $m^2.K/W$;

R_{qmin} is a minimum allowable resistance to heat transfer of the enclosing structure, $m^2.K/W$.

As required by Item 2.4 of DBN B.2.6-31:2006 [44], a minimum allowable value of resistance to heat transfer of the enclosing structure R_{qmin}, $m^2.K/W$, for production buildings should be established according to Table 2 of DBN B.2.6-31:2006 [44] depending on:

- the temperature in the facility operation area as per Appendix B [44];
- heat-to-humidity conditions as per Appendix G [44].
- thermal inertia of the enclosing structure D that is found by the formula (4) [44].

As follows from Appendix B [44], the construction object is located in the operation temperature area I.

As follows from Appendix G [44], at the given temperature of inside air in the cold period (≤12°C), a normal heat-to-humidity condition is assigned for the space with a relative humidity of inside air not exceeding 75%.

Under normal heat-to-humidity conditions in keeping with Appendix K [44], we assume “B” conditions for operation of material in the enclosing structures.

The thermal inertia for the structure assumed using the formula (4) DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{7} R_i \cdot S_i$$

where R_i is a thermal resistance, $m^2.K/W$, of a layer in the multi-layer enclosing structure;

S_i is an estimated heat absorption coefficient for a separate layer of the enclosing structure given operating condition B, $W/(m^2.K)$, according to Appendix L [44].

For the buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under *normal* heat-to-humidity condition for premises where D>1.5) must be:

- R_{qmin} = 1.7 $(m^2 \times K)/W$ (Table 2 [44] for wall cladding;
- R_{qmin} = 1.7 $(m^2 \times K)/W$ (Table 2 [44] for basement;
- R_{qmin} = 1.7 $(m^2 \times K)/W$ (Table 2 [44] for roof covering.

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition to meet the requirement (1) ($R_{\Sigma red} \geq R_{qmin}$), i.e. for the condition: ($R_{\Sigma red} = R_{qmin}$)

To verify the condition (1), the reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ ($m^2.K/W$), is found in accordance with Appendix I [44], Item 2.10, using the formula (I.1):

$$R_{\Sigma np} = \frac{1}{\alpha_в} + \sum_{1}^{i} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_з},$$

where α_B = 8.7 W/(m^2 x K) is a heat transfer coefficient, W/(m^2.K), of the inner surface of enclosing structure ([44], Appendix E);

α_3 = 23 W/(m^2 x K) is a heat transfer coefficient for winter conditions, W/(m^2 .K), of the outer surface of enclosing structure ([44], Appendix E);

δ_i is the thickness of the i-th layer of the structure, m;

λ_i is the heat conductivity, W/(m.K), of the i-th layer of the structure under the rated duty, according to Item 2.11 and Appendix L [44].

15.5.1 Calculation of Wall Claddings for Electrical Equipment Building, Fire Pump Station and Garage

The wall claddings are made from the materials as follows:

Electrical equipment building:

- corrugated sheets (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m$^{3)}$, thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.045 W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);
- Wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Table L.1 [44]).

Fire pump station:

- corrugated sheets (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m$^{3)}$, thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.045 W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);
- Wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Item 56, Table L.1 [44]).

Garage:

- corrugated sheets (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m$^{3)}$, thickness is to be defined by calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.045 W/(m.K);
- Ceresit CT 190 mortar (neglected for the calculation);
- Wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B, λ_B, is 0.27 W/(m.K) (Table L.1 [44]).

The thermal inertia for the structure assumed using the formula (4) [44] will roughly be:

$$D = \sum_{1}^{7} R_i \cdot S_i = \frac{0,3}{0,27} \cdot 3,98 = 4,42$$

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under normal heat-to-humidity condition for premises where D>1.5) must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) DBN B.2.6-31:2006 [44]:

$$R_{констр.} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{\delta}{0,045} + \frac{0,3}{0,27}$$

$$R_{констр.} = \frac{\delta}{0,045} + 1,111$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8,7} + \left(1,111 + \frac{\delta}{0,045}\right) + \frac{1}{23} = 0,115 + 1,111 + \frac{\delta}{0,045} + 0,043 = 1,269 + \frac{\delta}{0,045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}$=R_{qmin})

($R_{\Sigma red}$ = 1.269 + δ/0.045) = (R_{qmin}= 1.7)

1.269 + δ/0.045 = 1.7

δ/0.045 = 1.7 – 1.269

δ = (1.7 – 1.269) x 0.045 = 0.019395 m

δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1, DBN B.2.6-31:2006 [44], regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.380 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

15.5.2 A Calculation of Wall Basement for Electrical Equipment Building, Fire Pump Station and Garage

The wall basement is made from the materials as follows:

Electrical equipment building:

- 10 mm thick façade ceramic granite tile RAL 7004, an estimated heat transfer coefficient for the operational conditions B (λB = 1.1 W/(m.K) (Item 90, Table L.1 [44];
- Ceresit Cm 17 bonding aggregate;
- Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);

- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table L, [44]).

Fire pump station:

- 10 mm thick façade ceramic granite tile RAL 7004, an estimated heat transfer coefficient for the operational conditions B (λB = 1.1 W/(m.K) (Item 90, Table L.1 [44];
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table L, [44]).

Garage:

- 10 mm thick façade ceramic granite tile RAL 7004, an estimated heat transfer coefficient for the operational conditions B (λB = 1.1 W/(m.K) (Item 90, Table L.1 [44];
- Ceresit Cm 17 bonding aggregate (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- reinforcing fiberglass mesh (neglected for the calculation);
- Ceresit CT 190 mortar (neglected for the calculation);
- IZOVAT-145 mineral wool slabs (density of 145 kg/m^3), thickness to be defined by calculation, an estimated heat transfer coefficient for the operational conditions B (λB = 0.045 W/(m.K);
- Ceresit CT 190 mortar for bonding heat-insulation slabs (neglected for the calculation);
- wall from 300 mm thick foam concrete blocks, density of 700 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.27 W/(m.K) (Item 56 of Table L, [44]).

The thermal inertia for the structure assumed using the formula (4) DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{n} R_i \cdot S_i = \frac{0,01}{1,1} \cdot 12,55 + \frac{0,3}{0,27} \cdot 3,98 = 4,54$$

For the wall cladding of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under normal heat-to-humidity condition for premises where D>1.5) must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44]

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) DBN B.2.6-31:2006 [44]:

$$R_{\text{конст.}} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{0,01}{1,1} \frac{\delta}{0,045} + \frac{0,3}{0,27}$$

$$R_{\text{конст.}} = \frac{\delta}{0,045} + 1,12$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma \text{пр}} = \frac{1}{8,7} + \left(1,12 + \frac{\delta}{0,045}\right) + \frac{1}{23} = 0,115 + 1,12 + \frac{\delta}{0,045} + 0,043 = 1,278 + \frac{\delta}{0,045}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

($R_{\Sigma red}$=R_{qmin})

($R_{\Sigma red}$ = 1.278 + δ/0.045) = (R_{qmin}= 1.7)

1.278 + δ/0.045 = 1.7

δ/0.045 = 1.7 – 1.278

δ = (1.7 – 1.278) x 0.045 = 0.01899 m

δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1, DBN B.2.6-31:2006 [44], regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

[$R_{\Sigma red}$ = 2.389 m^2.K/W] ≥ [R_{qmin} = 1.7 m^2.K/W].

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-145 mineral wool slabs (density of 145 kg/m^3).

15.5.3 A Calculation of Roof Covering for Electrical Equipment Building and Fire Pump Station

The roof covering is made from the materials as follows:

Electrical equipment building:

- 10 mm thick pebble-dash (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1 layer - 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);

- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 220 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K) (Item 81, Table L.1 [44]).

Fire pump station

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.046 W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is λ_B = 0.042 W/(m.K);
- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 220 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is λ_B = 2.04 W/(m.K) (Item 81, Table L.1 [44])

The thermal inertia for the structure assumed using the formula (4) DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{n} R_i \cdot S_i = \frac{0{,}04}{0{,}046} \cdot 0{,}77 + \frac{0{,}22}{2{,}04} \cdot 18{,}95 = 2{,}714$$

For the roof covering of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under normal heat-to-humidity condition for premises where D>1.5) must be:

R_{qmin} = 1.7 (m^2 x K)/W (Table 2 [44])

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) DBN B.2.6-31:2006 [44]:

$$R_{констр.} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{0{,}04}{0{,}046} + \frac{\delta}{0{,}042} + \frac{0{,}22}{2{,}04}$$

$$R_{констр.} = \frac{\delta}{0{,}042} + 0{,}978$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8{,}7} + \left(0{,}978 + \frac{\delta}{0{,}042}\right) + \frac{1}{23} = 0{,}115 + 0{,}978 + \frac{\delta}{0{,}042} + 0{,}043 = 1{,}136 + \frac{\delta}{0{,}042}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

$(R_{\Sigma red}=R_{qmin})$

$(R_{\Sigma red} = 1.136 + \delta/0.042) = (R_{qmin} = 1.7)$

$1.136 + \delta/0.042 = 1.7$

$\delta/0.042 = 1.7 – 1.136$

$\delta = (1.7 – 1.136) \times 0.042 = 0.023688$ m

δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1, DBN B.2.6-31:2006 [44], regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

$[R_{\Sigma red} = 2.326\ m^2.K/W] \geq [R_{qmin} = 1.7\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.5.4 Calculation of Garage Building Roof Covering

<u>The roof covering</u> is made of the following materials:

- 10 mm thick pebble-dash for the roof covering (pebble sized 3 to 10 mm) (neglected for the calculation);
- 1.2 mm thick PVC PROTAN membrane (Ukraine-made) mounted mechanically (neglected for the calculation);
- 40 mm thick insulant - 1 layer of IZOVAT mineral wool slabs, density of 200 kg/m^3, an estimated heat transfer coefficient for operational conditions B is $\lambda_B = 0.046$ W/(m.K);
- insulant – 1 layer of IZOVAT mineral wool slabs, density of 110 kg/m^3, thickness to be determined by the calculation, an estimated heat transfer coefficient for operational conditions B is $\lambda_B = 0.042$ W/(m.K);
- sloping from IZOVAT mineral wool slabs (density of 110 kg/m^3, neglected for the calculation);
- vapor seal – 200 µ thick polyethylene film (neglected for the calculation);
- foundation - 220 mm thick reinforced concrete plate, an estimated heat transfer coefficient for operational conditions B is $\lambda_B = 2.04$ W/(m.K) (Item 81, Table L.1 [44])

The thermal inertia for the structure assumed using the formula (4) DBN B.2.6-31:2006 [44] will roughly be:

$$D = \sum_{1}^{n} R_i \cdot S_i = \frac{0{,}05}{0{,}046} \cdot 0{,}77 + \frac{0{,}22}{2{,}04} \cdot 18{,}95 = 2{,}884$$

For the roof covering of buildings in the operational temperature area I, a minimum allowable heat transfer resistance (under normal heat-to-humidity condition for premises where D>1.5) must be:

$R_{qmin} = 1.7\ (m^2 \times K)/W$ (Table 2 [44])

For a multi-layer structure, the heat transfer resistance R_{const} (m^2.K/W) is found by the formula (5) DBN B.2.6-31:2006 [44]:

$$R_{конст.} = \sum_{1}^{n} \frac{\delta_i}{\lambda_i} = \frac{0{,}05}{0{,}046} + \frac{\delta}{0{,}042} + \frac{0{,}22}{2{,}04}$$

$$R_{конст.} = \frac{\delta}{0{,}042} + 1{,}195$$

The reduced heat transfer resistance of the enclosing structure, $R_{\Sigma red}$ (m^2.K/W), is found by (I.1):

$$R_{\Sigma пр} = \frac{1}{8{,}7} + \left(1{,}195 + \frac{\delta}{0{,}042}\right) + \frac{1}{23} = 0{,}115 + 1{,}195 + \frac{\delta}{0{,}042} + 0{,}043 = 1{,}353 + \frac{\delta}{0{,}042}$$

A minimum thickness, δ (m), of the covering heat insulation is found from the boundary condition:

$(R_{\Sigma red}=R_{qmin})$

$(R_{\Sigma red} = 1.353 + \delta/0.042) = (R_{qmin}= 1.7)$

$1.353 + \delta/0.042 = 1.7$
$\delta/0.042 = 1.7 – 1.353$
$\delta = (1.7 – 1.353) \times 0.042 = 0.014574$ m
δ is accepted as 50 mm basing on the slab fabrication conditions.

The requirements of Item 2.1, DBN B.2.6-31:2006 [44], regarding the mandatory compliance with the condition (1) with the assigned thickness of the heat-insulation layer being 50 mm (0.05 m) are met:

$[R_{\Sigma red} = 2.543\ m^2.K/W] \geq [R_{qmin} = 1.7\ m^2.K/W]$.

The accepted thickness of the heat-insulation layer is 50 mm (0.05 m) for IZOVAT-110 mineral wool slabs (density of 110 kg/m^3).

15.6 Conclusions

During the designing process, an economic effect from the use of enclosing structures of the buildings having façade heat insulation is attained through increased thermal resistance of the enclosing structures and minimized heat losses.

For the design of CSFSF buildings and facilities, the enclosing structures have been chosen basing on the thermotechnical calculations that would minimize heat losses when the CSFSF buildings and facilities are in operation and optimize them when under construction.

Thicknesses of heat insulation layers for the buildings' enclosing structures have been adopted on the basis of the thermotechnical calculations. Results of the thermotechnical calculations are shown in Table 15.1 below.

Table 15.1. Results of a Thermotechnical Calculation of Enclosing Structures

Description	Values of Thermotechnical Calculation Parameters				
	D	R_{qmin}	$R_{\Sigma red}$	Insulant	δ
• Administrative building (CD facility): - outside walls	-	3.3	4.078	IZOVAT 80	100
- outside walls basement	-	3.3	3.861	IZOVAT 145	100
- roof covering	-	4.95	6.1	IZOVAT 110	200
• Guard building (CD facility): - outside walls	-	3.3	3.708	IZOVAT 80	100
- outside walls basement	-	3.3	3.491	IZOVAT 145	100
- roof covering	-	4.95	5.88	IZOVAT 110	200
• Checkpoint 1: - outside walls	-	3.3	3.893	IZOVAT 80	100
- outside walls basement	-	3.3	3.491	IZOVAT 145	100
- roof covering	-	4.95	5.88	IZOVAT 110	200
• Checkpoint 2: - outside walls	-	3.3	3.893	IZOVAT 80	100
- outside walls basement	-	3.3	3.491	IZOVAT 145	100
- roof covering	-	4.95	5.97	IZOVAT 110	200
• Acceptance building: • *within axes 1-8, A-B:*					
- outside walls	2.79	1.7	1.861	IZOVAT 145	70
- roof covering	3.457	1.7	2.364	IZOVAT 110	50
• *within axes 1-8, B-D:*					
- outside walls	-	3.3	3.491	IZOVAT 145	100
- outside walls basement	-	3.3	3.491	IZOVAT 145	100
- roof covering	-	4.95	5.88	IZOVAT 110	200

Description	Values of Thermotechnical Calculation Parameters				
	D	R_{qmin}	$R_{\Sigma red}$	Insulant	δ
• Heated portion of maintenance building with MPC storage room: - outside walls	4.42	1.7	2.380	IZOVAT 145	50
- outside walls basement	4.54	1.7	2.389	IZOVAT 145	50
- roof covering	2.714	1.7	2.326	IZOVAT 110	50
• Electrical equipment building: - outside walls	4.42	1.7	2.380	IZOVAT 145	50
- outside walls basement	4.54	1.7	2.389	IZOVAT 145	50
- roof covering	2.714	1.7	2.326	IZOVAT 110	50
• Fire pump station: - outside walls	4.42	1.7	2.380	IZOVAT 145	50
- outside walls basement	4.54	1.7	2.389	IZOVAT 145	50
- roof covering	2.714	1.7	2.326	IZOVAT 110	50
• Garage: - outside walls	4.42	1.7	2.380	IZOVAT 145	50
- outside walls basement	4.54	1.7	2.389	IZOVAT 145	50
- roof covering	2.884	1.7	2.543	IZOVAT 110	50
Note: The following conventions for the parameters are used in Table: D – thermal inertia for the structure accepted R_{qmin} – a minimum allowable resistance to heat transfer of enclosing structure, m^2.K/W $R_{\Sigma red}$ – reduced resistance to heat transfer of enclosing structure, m^2.K/W δ – the insulant thickness assumed by rounding the design value upward to the nearest value of the insulant standard size manufactured, mm					

From an analysis of the numerical values of the calculation results presented in the Table 15.1, it may be concluded that all the chosen heat insulation structures and materials characteristically meet the requirement to the basis inequations of the calculation, i.e. the reduced heat transfer resistance of all the types of enclosing structures $R_{\Sigma red}$ is greater than the minimum allowable values of resistance to heat transfer of the enclosing structures R_{qmin}. Thus, the design options on the heat insulation for all of the CSFSF buildings and facilities will provide for minimum allowable heat losses during the entire calendar year that will allow compliance with the required regulatory and legal documents for energy efficiency.

15.7 Annual Heat Consumption by Heating Systems

A value of estimated annual heat consumption by the heating system of the guard building, Q_{ann}, GJ, should be defined by the formula:

$$Q_{ann\ heat} = [0.086 \times Q_{heat} \times S_{heat} \times a \times b \times c] / (t_i - t_o) \qquad 15.4$$

where t_o = minus 22°C is the temperature of outside air (temperature of the coldest five-day stretch having a reliability of 0.92 according to Table 2 of DSTU-H B.1.1-27:2010 [5];

t_i = 18°C is an estimated averaged temperature of inside air, °C, that is accepted as required by the design standards for variable-purpose premises whilst considering a temperature buildup versus a ceiling height;

S_{heat} = 3185.6 is a number of degree-days in the heating period that are found by:

$$S_{heat} = (t_i - t_{heat\ per})Z_{heat\ per} \qquad (15.5)$$

where $t_{heat\ per}$ = -0.1 is a mean temperature, ^oC, of a period having a mean daily air temperature which is lower than or equal to 8^oC, DSTU-H B.1.1-27:2010 [106];

$Z_{heat\ per}$ = 176 is a duration, days, of a period having a mean daily air temperature which is lower than or equal to 8^oC, DSTU-H B.1.1-27:2010 [5];

S_{heat} = (18 + 0.1) x 176 = 3185.6 degree-days;

a = 0.8 is a coefficient which is to be taken into consideration if a heating system is equipped with automatic devices for lowering heating capacity in non-duty hours (a = 1 in this case);

b = 0.9 is a coefficient which is to be taken into consideration if the heating units are equipped with heat regulators;

c = 1 is a coefficient which covers absence of an automatic façade-to-façade regulation for the system;

Q_{heat} is an estimated heating capacity, kW, of a heating system.

The estimated heating capacity of the heating system for the guard building, Q_{heat}, kW, is found by the formula:

$$Q_{heat} = Q_1 \times b_1 \times b_2 \times b_3 + Q_2 - Q_3 \qquad (15.6)$$

where Q_1 = 46 kW is estimated heat losses in the building through the enclosing structures;

b_1 = 1.11 is an averaged coefficient for metering an additional heat flow in the heating units installed;

b_2 = 1.02 is a coefficient for metering additional heat losses by the heating units installed near outside enclosures;

b_3 = 1.1 is a coefficient which should be taken into account once the heating units are equipped with heat regulators;

Q_2 is estimated heat losses, kW, in the pipelines which pass through non-heated spaces. This value is neglected in the calculation since the electric heating system is used;

Q_3 is the heat flow which regularly comes from lighting, people, etc. This is not included in the calculation due to its minor value.

The estimated heating capacity of the heating system is then as follows:

Q_{heat} = 46 x 1.11 x 1.02 x 1.1 = 57.29 kW.

The value of the estimated annual heat consumption by the heating system, Q_{ann}, GJ, is found as follows:

$Q_{ann\ heat}$ = [0.086 x 57.29 x 3185.6 x 1 x 0.9 x 1] / (18 + 22) = 353.14 GJ x 1000 x 0.000278 = 98.17 MW.

The heat consumed annually for heating inlet air for through-flow ventilation system which is in one-shift operation, kJ/yr, is found by:

$$Q = 0{,}143_{nmc}G_n\Delta t_{M1}K_3K_1 \qquad (15.7)$$

where n = 5 is the number of working days in a week;

m = 8 is the duration of a shift, hr;

c is an air specific heat which is 1.005 kJ/kg^oC;

G_n is a maximum consumption of inlet air, kg/hr;

where $t_{ave\ cold}$ is a mean air temperature in the coldest month that is found from DSTU-HB.1.1-27:2010;

A_{cold} is a mean temperature amplitude, °C, in the year's coldest month that is found for temperature from Appendix 2 to DSTU-HB.1.1-27:2010;

K_1 is a coefficient defined using Table 2 of Guide 9.91 to SNiP 2.04/05-91(Construction Rules and Regulations) depending on the duration of the system service during a day;

K_2 is a coefficient defined using Table 2 of Guide 9.91 to SNiP 2.04/05-91(Construction Rules and Regulations) depending on the time that falls on the middle of the system's daily work period;

M_1 = 219 is duration of the period when the air heater of the ventilation system consumes heat, days;

$$M_1 = 182.5(\Delta t_k/\Delta t_{k,g})^{0.5} \qquad (15.10)$$

$\Delta t_{k,g}$) is for a through-flow ventilation system

$$\Delta t_k = t_g - t_{cold} \qquad (15.11)$$

K_3 and K_4 are the coefficients defined using Table 3 in Guide 9.91 to SNiP 2.04/05-91(Construction Rules and Regulations) depending on the duration of the heat-consuming period.

For the garage:

Q=0.143x5x8x1.005x5150x1.2x21.08x230x1.06x1.615=112296149.18 kJ/g=31.22 MW

The calculation has been accomplished for all the buildings under design. The results are summarized in Table 15.2.

Table 15.2. Results of Calculations of Annual Heat Consumption by Heating Systems

Building	Estimated averaged inside air temper.	Degree-days in construct. Period (heating)	Heat losses of building, kW	Estimated annual heat consumption by building heating system, Q_{ann}, MW	Inlet air temper., °C	Inlet air consumed, m³/hr	Estimated annual heat consumed by building through-flow ventilat. Systems, Q_{ann}, MW
Acceptance building	18	3185.6	246.0	525.01	10	20000	58.18
					16	5980	31.12
					18	8905	53.98
Maintenance building with MPC storage room	16	2833.6	55.0	109.91	16	2740	14.26
					18	1250	7.58
Administrative building (w/o CD)	18	3185.6	47.0	100.31	18	5180	31.40
Administrative building (with CD)	10	1777.6	5.0	7.44	5	1110	1.53
Electric equipment building	10	1777.6	6.0	8/93	16	2840	14.78
Garage	10	1777.6	97.5	145.14	18	5150	31.22
					24	9500	80.26
					16	13000	66.88
Fire pump station	5	897.6	18/0	16.04	-	-	-
Guard building (w/o CD)	18	3185.6	46.0	98.17	18	1895	51.77
					18	1560	9.46

Guard building (with CD)	10	1777.6	4.5	6.70	5	1110	1.53
Checkpoint 1	18	31.85.6	33.0	70.43	18	1000	27.32
Checkpoint 2	18	3185.6	7.0	14.94	-	-	-
Module building (container unit)	10	1777.6	2.0	2.98	-	-	-
Total for the site:				1106.00			481.27

16 AVAILABILITY OF CSFSF FOR MOBILITY IMPAIRED PEOPLE

The activities at CSFSF relate to those with harmful work environment (a letter from Separated Enterprise Atomproektinzhiniring No 03-46/388 dated 20.03.2015).

As required by Article 169 of the Ukraine Labor Code, the personnel that will be engaged in the activities at CSFSF must attend a medical examination through a procedure specified in The Procedure for Medical Examinations for Workers of Certain Categories. The Procedure was approved by the Ukraine Ministry of Health under its Order No 246 of 21.05.2007 and registered by Ukraine Ministry of Justice under No 846/14113 of 23.07.2007.

In compliance with the customary practice and policy of DP NAEK ENERGOATOM, admittance to work at CSFSF is given to personnel having appropriate qualification characteristics, a required level of education and not having medical and psychophysical counter-indications concerning professions.

Characteristics of the personnel employed must meet the qualification requirements put in given position.

Mobility impaired people are not thought to be involved in the CSFSF activities.

17 PERFORMANCE INDICATORS

Performance indicators are given in Table 17.1.

Table 17.1. Performance Indicators

Indicator	Unit of measurement	Quantity Including Start-Up Facilities (SUF)					
		Total	SUF-1	SUF-2	SUF-3	SUF-4	SUF-5
Type of Construction – New Construction							
Site area	ha	18.2	18.2	-	-	-	-
Development area	ha	4.9	4.9	-	-	-	-
Life	year	100	-	-	-	-	-
Capacity, including:	HI-STORM cask	458	4	33	33	24	32
For VVER-100 reactor	HI-STORM cask	388	3	28	29	21	27
For VVER-440 reactor	HI-STORM cask	70	1	5	4	3	5
Total estimated cost of construction in current prices as at 10.11.2016	K UAH	37 217 475.533	4 760 662.161	2 494 340.966	2 481 843.368	1 806 127.136	2 257 073. 918
including:							
construction work	K UAH	445 456.808	415 173.660	2 194.832	2 194.832	1 602.412	2 134.991
equipment	K UAH	30 455 845.778	3 440 685.221	2 076 288.009	2 065 873.344	1 503 400.129	1 878 624.997
others	K UAH	6 316 172.947	904 803.280	415 858.125	413 775.192	301 124.595	376 313.930
Additionally, cost of social-purpose facilities (10% of total construction estimate)	K UAH	3 721 747.553	476 066.216	249 434.097	248 184.337	180 612.714	225 707.392
Construction labor input	K man-hour	1756.57931	1685.00748	5.103	5.103	3.7113	5.06417
Number of jobs created	job	95	95	-	-	-	-
newly created jobs, incl.:	job	95	95	-	-	-	-
Total number of workmen	man	161	161	-	-	-	-
Construction duration	month	198	30	12	12	12	12
Annual needs for:							
water	K m^3	3.31	-	-	-	-	-
power	K kW/yr	4750.98	-	-	-	-	-
oil products (Diesel fuel)	t	19.7	-	-	-	-	-

Table 17.2. Performance Indicators (continued)

Indicator	Unit of measurement	Quantity Including Start-Up Facilities (SUF)				
		SUF-6	SUF-7	SUF-8	SUF-9	SUF-10
Site area	ha	-	-	-	-	-
Development area	ha	-	-	-	-	-
Life	year	-	-	-	-	
Capacity, including:	HI-STORM cask	32	32	34	32	32
For VVER-100 reactor	HI-STORM cask	27	27	26	27	27
For VVER-440 reactor	HI-STORM cask	5	5	8	5	5
Total estimated cost of construction in current prices as at 10.11.2016	K UAH	2 257 073.918	2 257 073.918	2 404 327.816	2 257 073.918	2 257 073.918
including:						
construction work	K UAH	2 134.991	2 134.991	2 270.755	2 134.991	2 134.991
equipment	K UAH	1 878 624.997	1 878 624.997	2 001 193.246	1 878 624.997	1 878 624.997
others	K UAH	376 313.930	376 313.930	400 863.815	376 313.930	376 313.930
Additionally, cost of social-purpose facilities (10% of total construction estimate)	K UAH	225 707.392	225 707.392	240 432.782	225 707.392	225 707.392
Construction labor input	K man-hour	5.06417	5.06417	5. 40147	5.06417	5.06417
Number of jobs created	job	-	-	-	-	-
newly created jobs, incl.:	job	-	-	-	-	-
Total number of workmen	man	-	-	-	-	-
Construction duration	month	12	12	12	12	12
Annual needs for:						
water	K m^3	-	-	-	-	-
power	K kW/yr	-	-	-	-	-
oil products (Diesel fuel)	t	-	-		-	-

Table 17.3. Performance Indicators (continued)

Indicator	Unit of measurement	Quantity Including Start-Up Facilities (SUF)				
		SUF-11	SUF-12	SUF-13	SUF-14	SUF-15
Site area	ha	-	-	-	-	-
Development area	ha	-	-	-	-	-
Life	year	-	-	-	-	-
Capacity, including:	HI-STORM cask	32	32	34	34	38
For VVER-100 reactor	HI-STORM cask	27	27	29	29	34
For VVER-440 reactor	HI-STORM cask	5	5	5	5	4
Total estimated cost of construction in current prices as at 10.11.2016	K UAH	2 257 073.918	2 257 073.918	2 397 423.605	2 397 423.605	2 675 809.450
including:						
construction work	K UAH	2 134.991	2 134.991	2 270.755	2 270.755	2 533.870
equipment	K UAH	1 878 624.997	1 878 624.997	1 995 439. 737	1 995 439.737	2 270 151.376
others	K UAH	376 313.930	376 313.930	399 713.113	399 713.113	446 124.204
Additionally, cost of social-purpose facilities (10% of total construction estimate)	K UAH	225 707.392	225 707.392	239 742.360	239 742.360	267 580.945
Construction labor input	K man-hour	5.06417	5.06417	5.40147	5.40147	6.00093
Number of jobs created	job	-	-	-	-	-
newly created jobs, incl.:	job	-	-	-	-	-
Total number of workmen	man	-	-	-	-	-
Construction duration	month	12	12	12	12	12
Annual needs for:						
water	K m^3	-	-	-	-	-
power	K kW/yr	-	-	-	-	-
oil products (Diesel fuel)	t	-	-	-	-	-

18 R&D SUPPORT

18.1 Methodological Support and Work Objective

CSFSF is a nationwide nuclear unit. According to Appendix B to DBN B.1.2-5:2007 [105], the nuclear energy facilities of categories I and II of responsibility for nuclear safety are subject to mandatory R&D support.

As per Atomic Energy Standard 5.6 [7], the category I and II facilities include, among other CSFSF units:

- Acceptance building – ranked to the nuclear safety category I as per Atomic Energy Standard 5.6 [7],
- Cask storage area - ranked to the nuclear safety category II as per Atomic Energy Standard 5.6 [7].

The rest of the buildings and facilities pertain to the nuclear safety category III as per Atomic Energy Standard 5.6 [7].

At CSFSF, a "dry" technique for SNF storage in inert atmosphere is utilized using the Holtec technology (USA). It is for the first time that a technology like this is implemented in Ukraine. A technology similar to the CSFSF one was implemented at Zaporizzhya NPP's Dry Spent Fuel Storage Facility (DSFSF). Differences in the technologies do not allow full-scale application of DSFSF experience to CSFSF.

A service life designed for CSFSF is 100 years. CSFSF is intended to accept SNF from Rivne NPP, Khmelnitsky NPP and Yuzhoukrainsk NPP. That is, delivery of SNF to CSFSF will be provided in special transport containers by using general-use railway services.

CSFSF site is a location surrounded by the villages of Staraya Krasnitsa, Buryakovka, Chistogalovka and Stechanka, Kiev Region, in the exclusion zone which is contaminated radioactively due to Chernobyl disaster.

A primary goal of the R&D support is to tackle the problems which are not covered by regulatory documents and which can spring up at various stages of the construction facility's lifespan.

A main task of the R&D support is to address design and construction problems with a minimum risk of errors in the conditions that are not regulated by applicable standards and rules and in the absence of sufficient expertise or direct implications in the domestic practice.

Basic efforts under the R&D support include examinations, scientific survey, observation of the facility's technical state, surveys, study of building materials characteristics, verification of compliance with requirements of the construction standards and technical documentation of certain structures and accepted construction solutions, engineering survey, analyses of technical concepts for compliance with established requirements, and others.

18.2 Source Data

A CSFSF isometric diagram is shown in Fig. 18.1.

Fig. 18.1 CSFSF Isometric Diagram

Engineering surveys for the design stage have been completed in full. Currently, there is a forest growing on the site. Following preparatory work, it is necessary for category I and II buildings as per standard 5.6 [7] to carry out additional survey along the perimeter of building envelope with a grid of reference as required by the applicable survey standards.

In order to clarify layout options for the site, a need will be to take a more detailed topographic survey as it is impossible to show a site level exactly after the is deforested and stumped out.

Holtec International, a U.S. company, is a developer of the equipment for handling SNF for CSFSF. The development is carried out in accordance with the U.S. standard requirements with due account for the Ukrainian regulatory documents. The equipment includes metal, non-metal, reinforced concrete and concrete elements. The equipment designer has no experience in the equipment handling SNF from VVER reactors, however, they have a considerable experience in handling SNF from PWR reactors. The equipment design uses US-made materials including concrete.

HI-STORM storage cask design uses biological protection concrete which should retain its properties for as long as 100 years. Research is required to develop the composition of the concrete with Ukraine-made components to be used.

A cask transfer facility is to be designed for reloading MPCs from HI-STAR transport casks to HI-STAR storage casks. The cask transfer facility is being designed to U.S. standards using US-made materials (concrete, metal, reinforcement). The facility will be installed and on and connected with the foundation plate of the acceptance building. The acceptance building is designed in compliance with the requirements of the Ukrainian regulatory documents with Ukraine-made materials to be used. Additional facilities will have to be designed to link the acceptance building's foundations with the transfer facility.

The HI-STORM storage cask manufactured and painted in the USA will be operated in the Kiev Region conditions with SNF from VVER reactors at Ukraine's NPPs. It will be required to conduct cycles of observations in different seasons of the year in order to decrease likely failures and elaborate maintenance charts.

At the design stage, dimensioning calculations of buildings and facilities have been made in regard to extreme loads for buildings and facilities of categories I and II on responsibility for nuclear safety according to standard 5.6 for nuclear power plants [7]. Holtec is to deliver the main 180/20 t crane for the acceptance building. The crane is being designed to European regulatory documents. After a crane manufacturer is selected, it will be required for the next design stage to carry out checking calculations of the building with the crane manufacturer's data taken into account.

For developing a CSFSF operating procedure, it will be needed to develop process charts for operations to be undertaken with Holtec equipment and SNF from VVER reactors. In order to prevent personnel from being affected by dose loads as the operating charts are worked out, there will be a need for equipment models.

Weight of a HI-STORM storage cask filled with MPCs containing spent fuel assemblies (SFA) is up to 180 t. A total number of casks on the site is 458. The casks are put upon foundation plates that are 180 and 170 m long and 9 m wide. Roads having a width of up to 9 m are provided between the foundation plates for wheeled transport. The design envisions expansion joints after each 15 m to prevent influence of sequence in setting the casks upon the foundation plates. Confirmation of the design solution will require observation over yield of the plates.

The cask transfer facility inside the acceptance building is separated from the main foundation plate with expansion joints. Work to be done to build this unit will require development of a special design for the works and eventually monitor the yields.

18.3. List of Work Items for R&D Support

Nos	R&D Support Work Items	Life Cycle	Potential Contractor
1	Engineering survey for acceptance building and cask site	Design	KIZI
2	Topographic survey of CSFSF site after deforesting and stumping	Design	KIZI
3	Analysis of Holtec equipment for compliance with applicable regulatory documents	Design	
4	Analysis of materials used for Holtec equipment	Design	
5	Analysis of main crane for compliance with Ukrainian regulatory documents	Design	
6	Interaction of acceptance building structures with transfer facility	Design	KIEP
7	Building structures monitoring program	Design	KIEP
8	Checking calculations of acceptance building considering crane selected	Design	KIEP
9	Development of special design for work on transfer facility in acceptance building	Design	
10	Development of individual prices for commissioning works with Holtec equipment	Design	

Nos	R&D Support Work Items	Life Cycle	Potential Contractor
11	Research "Development of Concrete Having Higher Special Operating Properties"	Construction	Ukrditsement State Research Institute
11.1	Selection and analysis of scientific and technical literature and other information materials; Development of analytical review; Development of operational plan	Construction	Ukrditsement State Research Institute
11.2	Development of algorithms for calculating and modeling procedures for selection of concrete composition; Preliminary development of special beton recipe including studies of raw materials for special concrete	Construction	Ukrditsement State Research Institute
11.3	Manufacture of exploratory prototypes and related tests for durability, thermal stability and resistance to radiation; Generalization and assessment of findings; Refinement of special beton recipe	Construction	Ukrditsement State Research Institute
11.4	Development of standard technical and process documentation on concretes having higher special operating properties basing on the research performed including determination of required equipment, machines, mechanisms and their technical characteristics	Construction	Ukrditsement State Research Institute
12	Observation over acceptance building yields	Construction	
13	Observation over storage site yields	Construction	
14	Development of equipment models for process charts	Construction	
15	Development of process charts for operations	Construction	
16	Observation over storage cask	Operation	

17	Observation over storage site foundations	Operation	
18	Monitoring of HI-STORM emissions	Operation	
18.1	Development of observation program	Operation	
18.2	Observations depending on ambient conditions Operation		

18.4 Arrangement of R&D Support Activities

The R&D support work is to be performed in accordance with the R&D support program that is to be developed taking into consideration the applicable regulatory documents and should generally contain the following sections:

- Justification for the support activities;
- Objective and intent of the support activities;
- Source data for the activities;
- Work Contractors;
- Work stages and deadlines;
- A list of materials to be provided to the Customer at work stages and after completion of work;
- A procedure for accepting the R&D support activities.

The support activities must be executed under contracts between the Customer and the Contractor on bidding conditions.

The work may be performed by the main Contractor who may engage subcontractors for individual works or the Customer will develop an R&D support program to order services under separate contracts with Contractors.

19 CALCULATION OF A CONSEQUENCE (RESPONSIBILITY) CLASS AND A DIFFICULTY CATEGORY

The consequence class and difficulty category have been calculated in conformity with DSTU H B.1.2-16:2013 Standard “Determination of Consequence (Responsibility) Class and Difficulty Category for Construction Projects” [131].

According to Item 4.4 of DSTU H B.1.2-16:2013 [131], a consequence (responsibility) class is determined for each building and facility separately. For CSFSF, the consequence class is determined basing on the greatest characteristics of possible consequences.

Below are the source data for evaluating a consequence class:

- A number of personnel who are permanently inside a building/facility, i.e. those who are there for not over 8 hours a day and not over 150 days a year is given in Table 19.1.
- A number of personnel who are periodically inside a building/facility, i.e. those who are there for not over 8 hours a day and not over 150 days a year (in total of 45 to 1200 hours/year) is given in Table 19.1.
- A number of people who are outside CSFSF and for which violation of vital activity for more than three days is considered is presented in the letter by DAVZ No o1-2369/142 dated 28.10.2015 that is 274 persons, including:
  - in the radius of 3 km: Buryakovka RWDF – 35 persons, KP VEKTOR – 164 persons;
  - in the radius of 10 km: motor transport column - 28 persons, guard team No 3- 42 persons;
  - in the radius of 10 km in the former residential areas: temporary “self-settlers” – 2 persons in the village of Ilyintsy and 3 persons in Lubyanka.
- The CSFSF buildings and facilities do not relate to objects of cultural heritage in compliance with the Ukraine Law “On Protection of Cultural Heritage” No 1805-III of 08.06.2000 with amendments as of 12.02.2015 [129]:
- The CSFSF buildings and facilities do not relate to objects of engineering and transport infrastructure.
- For assessment of economic damages due to termination of operation or loss of integrity of the building or facility, data from facility-level estimates in Vol. 15.1 “Estimate Documents. Part 1. Estimate Summary and Facility-Level Estimates” was used.
- Service lives of buildings and facilities are given in Table 19.1.
- Minimum wages established under Article 8 of the Ukraine Law “On the State Budget of Ukraine for 2016” No 928-VIII of 25.12.2015 [128] are 1378 UAH since January 1.
- The list of buildings and facilities is in line with the breakdown of buildings and facilities in the project general plan (Vol. 2 “General Plan and Transport”).

19.1. Calculation of Consequence Class and Difficulty Category for a Facility in Total

Building/Facility	Specified period for operation of fixed assets	Depreciation charge factor	Number of people permanent-ly present in building	Number of people periodically present in building	Number of people present outside CSFSF (in 10 km zone). person	Cost of fixed assets, UAH	Possible material damage, UAH	Possible economic damage, min. wages	Conse - quenc e class	Difficu-lty catego-ry
Acceptance building	100	0.01	70	108	274	1 831 951 074	412 188 991.7	284 268	CC3	V
Cask storage site	100	0.01	0	13	274	23 965 453 628	5 392 227 066.3	3 718 777	CC3	V
Maintenance building with MPC storage room (with storage site and HI-STORM shoulder ring concreting bay	50	0.02	0	5	274	197 112 610	44 350 337.3	30 586	CC2	IV
Administrative building	50	0.02	38		274	22 987 137	5 172 105.8	3 567	CC2	III
Electric equipment building	50	0.02	0	2	274	27 538 810	6 196 232.3	4 273	CC2	III
Garage	50	0.02	0	4	274	126 037 654	28 358 472.2	19 558	CC2	IV
Petrol filling station	30	0.03	0	2	274	422 579	95 080.3	66	CC1	I
Fire pump station	50	0.02	0	4	274	7 431 993	1 672 198.4	1 153	CC1	I
Fire water tanks	50	0.02	0	2	274	1 313 853	295 616.9	204	CC1	I
Guard facilities	100	0.01	32	52	274	35 230 778	7 926 925.1	5 467	CC2	III
Checkpoint 1	50	0.02	18	50	274	16 790 312	3 777 820.2	2 605	CC2	III
Checkpoint 2	20	0.05	2	4	274	10 136 078	2 280 617.6	1 573	CC1	II

Building/Facility	Specified period for operation of fixed assets	Depreciation charge factor	Number of people permanent-ly present in building	Number of people periodically present in building	Number of people present outside CSFSF (in 10 km zone). person	Cost of fixed assets, UAH	Possible material damage, UAH	Possible economic damage, min. wages	Conse-quence class	Difficu-lty catego-ry
Rainfall runoff facilities	30	0.03	0	3	274	8 655 505	1 947 488.6	1 343	CC1	I
Sewerage pumping station	30	0.03	0	3	274	388 689	87 455.0	60	CC1	I
Oil collector (separator)	30	0.03	0	2	274	220 775	49 674.4	34	CC1	I
Telecommunication tower with module building	20	0.05	0	2	274	107 531 857	24 194 667.8	16 686	CC2	IV
ARMS control station	20	0.05	0	1	274	2 305 492	518 735.7	358	CC1	I
In-site railroads	30	0.03	0	9	274	679 441 149	152 874 258.5	105 431	CC2	IV

A possible economic damage was estimated as per Item 4 of DSTU-H B.1.2-16:2013 [131] by the formula:

$$\Phi = c\sum_{i}^{n} P_i\left(1 - \frac{1}{2}T_{ef} \times K_{a,i}\right) \tag{19.1}$$

where c is a coefficient which accounts for the relative portion of fixed assets that will completely be lost during a failure. The value is assumed to be 0.45;

P_i, UAH is the cost of fixed assets pursuant to data from facility-level estimate calculations of the summarized estimate calculation;

T_{ef}, years is an established service life of fixed assets;

Ka, I = 1/T_{ef} is a depreciation charge factor;

1450 UAH is minimum wages according to [128].

Conclusion: From the results of the calculation, a consequence class of the construction target is generally determined by the characteristics of the cask storage site and acceptance building. Basing on the material damage, the consequence class is CC3 and the difficulty category is V for the facility.

20 SCHEDULE OF QUANTITIES

The schedules of quantities are given in each Project volume by fields of specialization.

Abbreviations and Acronyms

ARMS	Automated Radiation Monitoring System
NPP	Nuclear Power Plant
VVER	Water-Water Power Reactor (a reactor of PWR type)
VCT	Vertical cask transporter (transfer vehicle)
BV	Waste holdup unit
LM	Lifting machinery
CP	Civil protection
CD	Civil defense
DP NAEK ENERGOATOM	State-owned Enterprise “Energoatom National Nuclear Energy Generating Company”
State-owned Specialized Enterprise Chernobyl NPP	State-owned Specialized Enterprise “Chernobyl Nuclear Power Plant”
CRZ	Compulsory resettlement zone
SPTA	Spare parts, tools and accessories
SA	Supervised area
RZ	Resettlement zone
WA	Work area
LRW	Liquid radioactive waste
PDM	Personal dosimetry monitoring
IRS	Ionizing radiation source
ETM	Engineering and technical measures
DMS	Dosimetry monitoring station
I&A	Instrumentation and automation
KP VEKTOR	Vektor Production Facilities
Checkpoint	Checkpoint
RL	Reference level
HFL	Highly flammable liquid
DI	Dose intensity
MHU	Ministry of Health of Ukraine
ICRP	International Commission on Radiological Protection
MPC	Multipurpose cask
EDR	Exposure or equivalent dose rate, as appropriate
HS	Hazardous substance
EIA	Environmental Impact Assessment
HRF	High-risk facility
OS	Occupational safety
SFA	Spent fuel assembly
SNF	Spent nuclear fuel
LLW	Low-level radioactive waste
RD	Regulatory documents
NRBU	Ukrainian Radiation Safety Standards
RI	Regulatory instrument
OP API	Separated Enterprise Atomproektinzhiniring
SNF	Spent nuclear fuel

RWDF	Radioactive waste disposal facility
PSAR	Preliminary Safety Analysis Report
PHF	Potentially hazardous facility
CMS	Construction Method Statement
RW	Radioactive waste
RS	Radiation safety
RAS	Radioactive substance
RN	Radionuclides
SPZ	Sanitary protection zone
PPE	Personal protective equipment
PRPE	Personal respiratory protective equipment
SOHF	Specialized occupational health facility
OSMS	Occupational safety management system
CMS	Control and management systems
OSH	Occupational safety and health
FA	Fuel assembly
TOR	Terms of Reference
M&R	Maintenance and repair
SRW	Solid radioactive waste
TE	Transuranium elements
RW	Radioactive waste
Emergency	Emergency
CSFSF	Central Spent Fuel Storage Facility
CTF	Cask transfer facility
NRS	Nuclear and radiation safety
NF	Nuclear fuel

Terms and definitions

Gas-aerosol discharge (discharge)	shall be understood as the ingress of radioactive substances into the atmospheric air from process loops and ventilation systems of a plant (NRBU-97)
Absorbed dose	shall be understood as the average dose absorbed in an organ or tissue calculated according to the formula where ___ is the aggregate energy released in an organ or tissue, ___ is the mass of an organ or tissue
Dose equivalent	shall be understood as a value defined as a product of the dose absorbed in a specific organ or tissue T by the radiation weighting factor wR
Effective dose	shall be understood as a sum of products of equivalent doses NT in specific organs and tissues by the appropriate tissue weighting factors wT
Allowed level	shall be understood as a derivative allowance for the ingress of radionuclides into a human organism over a calendar year, equivalent dose intensity, radionuclides concentration in the air, potable water and food, particle fluence rate, etc. averaged over a year and calculated for reference exposure conditions on the basis of dose limits
Radioactive contamination	shall be understood as the presence or propagation of radioactive substances in excess of their natural content in the environment and/or human body
Beyond-design-basis accident	shall be understood as an accident caused by accident initiator events not considered for design-basis accidents or an accident accompanied by additional failures of safety systems or personnel errors in comparison with design-basis accidents
Compulsory resettlement zone	shall be understood as an area subjected to the intensive contamination with the long-lived radionuclides with the soil contamination density exceeding the pre-accident level
Controlled zone	shall be understood as an area subjected to the intensified dosimetry monitoring
Supervised area of a facility	shall be understood as an area of the potential impact of radioactive discharges and emissions of a radiation/nuclear facility where technology processes are monitored to ensure radiation safety or a radiation/nuclear facility
Exclusion zone	shall be understood as an area of the evacuation of the population in 1986 (Law of Ukraine “On Legal Regime of the Area Subjected to Radioactive Contamination as a Result of the Chernobyl Disaster” # 791a-XII).
Reference levels	shall be understood as radiation hygiene regulations of Group One whose numeric values are set on the basis of the actual level of the radiation welfare attained at the radiation/nuclear facility or area in question. The RL value is specified by the management of the plant in concurrence with State Sanitary/Epidemiological Supervision agencies in order to keep exposure of personnel and/or population below dose limits and carry out radiation dosimetry control.
Critical event	shall be understood as an event which directly results in the materialization of a potential exposure. A critical event may be a combination of a number of particular ctitical events (NRBU-97/D-2000).

K-factor Exposure	shall be understood as the effective neutron multiplication factor shall be understood as the human exposure to the ionizing radiation from sources outside the human organism (external exposure) or from sources inside the human organism (internal exposure)
Potential exposure	shall be understood as the exposure of personnel and population considered during the design of practical activities and materializing after a certain critical event not covered by the regular technological process with the probability of occurrence below 1×10^{-2} per year
Design-basis accident	shall be understood as an infrequent event that can be expected at least once over the service life of the storage facility
Contaminated land	shall be understood as areas requiring radiation protection measures and other special interventions to be undertaken to limit the additional exposure caused by the Chernobyl accident and support regular economic activity
Reference probability of a critical event	shall be understood as a probability of occurrence of a critical event securing the non-exceedence of reference risks at various potential exposure dose levels
Risk (generalized risk)	shall be understood as a measure of the health hazard for a person affected by the exposure which is numerically equivalent to a product of two values: the exposure probability per unit time (year) and the probability of materialization of radiological stochastic and non-stochastic impact on the health of persons that can be subjected to the exposure in question
Acceptable risk	shall be understood as risk levels underlying the dose limits and threshold dose levels for termination of intervention for the population as prescribed by NRBU-97
Reference risk	shall be understood as numeric values of risks set for limiting potential exposure of the personnel and population which do not exceed acceptable risk levels
Buffer area (SZZ) of a facility	shall be understood as an area around a radiation/nuclear facility where the human exposure level under normal operating conditions can exceed the quota of the dose limit for population (Category B).

References

1. 19-571402/172-08-735. A research report in 2 books. State Enterprise – Kiev Institute of Engineering Explorations ENERGOPROEKT, 2015.
2. DBN B.1.1-3-97 Protection against dangerous geological processes. Engineering protection of territories, buildings and facilities against landslides and landfalls.
3. DBN B.1.1-24-2009 Protection against dangerous geological processes, harmful operational impacts and fire. Engineering protection against dangerous geological processes.
4. DBN B.1.1-25-2009 Protection against dangerous geological processes, harmful operational impacts and fire. Engineering protection of areas and facilities against underfloods and floods.
5. DSanPiN 2.2.4-171-10 Hygienic requirements to drinking water.
6. DBN B.2.1-10-2009 Foundations of facilities. Basic design provisions.
7. PiN AE-5.6 Standards for designing construction of nuclear power plants with varied-type reactors.
8. Ukraine Law "On Labor Protection" No 2694-XII of 14.10.1992.
9. NPAOP 0.00-4.12-05 Standard statute of a procedure for training and test of knowledge concerning labor protection.
10. PL-S.0.26.029-05 Provisions on labor protection service at DP NAEK Energoatom.
11. DSN 3.3.6.042-99 Sanitary standards for production spaces. Ukraine Ministry of Health, 1999.
12. DSP 6 177-2005-09-02 Basic health regulations for assurance of radiation safety in Ukraine.
13. NPAOP 0.00-4.01-08 Provisions on a procedure for providing workmen with overalls, safety footwear and other personal protective equipment.
14. NAPB B.03.002-2007 Rules for determination of explosive and fire dangerous categories of premises, buildings and outside installations.
15. NAOP 00-1.41-88 General rules for explosion safety of explosive and fire dangerous of chemical, petrochemical and oil refinery production facilities.
16. Electric installation code (PUE) – Kharkiv: Fort Publishing House, 2009.
17. DBN B.1.1-7-2002 Fire safety of construction projects.
18. DSTU B.2.6-49:2008 Constructions of buildings and facilities. Steel enclosures for staircases, balconies and roofs. General technical conditions.
19. DBN B.2.5-28-2006 Natural and artificial lighting.
20. DBN B.2.5-74:2013 Water supply. External networks and facilities. Basic design provisions.
21. DBN B.2.5-28-2006 Natural and artificial lighting.
22. DBN B.2.5-56-2014 Fire protection systems.
23. DSTU-H CEN/TS 54-14:2009 Fire alarm and warning systems. Part 14. Instructions on construction, design, installation, commissioning, operation and maintenance (CEN/TS 54-14:2004, IDT).
24. DSTU 4466-1:2008 Gaseous fire suppression systems. Design, installation, test, maintenance and safety. Part 1. General requirements (ISO 14520-1:2006, MOD).
25. DSTU 4466-8:2008 Gaseous fire suppression systems. Design, installation, test, maintenance and safety. Part 8. Fire suppressant HFC 125 (ISO 14520-8:2006, MOD).
26. DSTU B.2.5-38:2008 Installation of lightning protection of buildings and facilities (IEC 62305:2006, NEQ).

27. NAPB A.01.001-2014 Fire safety rules in Ukraine.
28. NAPB B.03.001-2004 Uniform code for fire extinguisher workability.
29. VBN B.1.1-034-03.307-2003 Fire control standards for designing nuclear power plants with pressurized water type reactors.
30. NAPB B.01.014-2007 Fire safety rules for operation of nuclear power plants.
31. NPAOP 0.00-1.01-07 Rules of construction and safe operation of hoisting cranes. Ukraine Committee for Labor Protection, 2007.
32. GOST 12.0.003-74* (CMEA Standard 790-77) Hazardous and harmful production factors. Classification.
33. NPAOP 0.0-1.17-07 Labor protection rules for overhead work.
34. NPAOP 40.1-1.01-97 Rules for safe operation of electric installations.
35. DBN B.2.2-28:2010 Buildings for administrative and household purposes.
36. GOST 12.4.176-89. SSBT Overalls for protection against radiation of heat.
37. GOST 12.4.016-87. SSBT Men's overalls for protection against elevated temperatures and radiation of heat. Specification.
38. Hygienic classification of labor in terms of harm and hazard of production environment factors, hardness and tension of labor process. State sanitary standards.
39. NP 306.2.105-2004 Basic provisions on safety of intermediate dry-type SNF storage facilities.
40. Ukraine Law "On Energy Efficiency" No 74/94-VR of 01.07.1994 (with amendments according to the Law during the period of 1999-2011).
41. DBN B.1.2-11:2008 Basic requirements to buildings and facilities. Energy saving. Ukraine Ministry of Regional Construction, Kiev, 2008.
42. DSTU 2339-94 Energy efficiency. Basic provisions.
43. DSTU 2155-93 Energy efficiency. Methods for determining cost efficiency of energy-saving measures.
44. DBN B.2.6-31:2006 Constructions of buildings and facilities. Heat insulation in buildings. Ukraine Ministry of Construction, Kiev, 2006.
45. DSanPiN 2.2.4-171-10 Hygienic requirements to drinking water intended for human consumption. Ukraine Ministry of Health, 2010.
46. DBN B.2.5-64:2012 In-house water piping and sewerage. Part 1. Design. Part 2. Construction.
47. DSTU 3580-97 Cold and hot water flow meters. General specifications.
48. ISO 4064-1:1993 Measurement of water flow in closed channels. Water meters for cold drinking water. Part 1. Specifications.
49. DBN B.1.2-14:2009 General principles of reliability and design safety of buildings, facilities, building structures and foundations. Ukraine Ministry of Regional Construction, Kiev, 2008.
50. SNiP II-89-80 General plans of industrial enterprises. USSR State Committee for Construction, 1980.
51. Resolution No 6 by Ukraine Cabinet of Ministers of 09.01.2014 "On Approval of a List of Economic Entities which are Designed by Meeting the Requirements of Civil Defence Engineering measures"
52. DSTU B.A.2.2-7:2010 Section with civil defence engineering measures as part of design documentation for construction facilities.
53. DBN B.1.2-4:2006 Civil defence engineering measures.
54. Ukraine Law "On Regulation of City-Planning Activities" No 3038-VI of 17.02.2011.
55. DSTU-H B A.2.2-10:2012 Instructions on arrangement of expert evaluation of design documentation on construction.
56. DBN B.1.2-9:2008 Basic requirements to buildings and facilities. Operational safety.

57. GOST 12.4.059-89 SSBT Construction. Safety fences. Specifications.
58. Convention on access to information, participation of public in decision-making processes and access to justice on environmental issues. UNO: Convention, an international documents dated 25.06.1998.
59. Ukraine Law “On Ratification of Convention on access to information, participation of public in decision-making processes and access to justice on environmental issues” No 832-XIV of 06.07.1999.
60. CNiP 3.05.06-85 Electrical devices.
61. DBN A.2.1-1:2008 Engineering survey for construction.
62. NPAOP 45.1-1.12-01 Safety rules for reconstruction of buildings and facilities of industrial enterprises.
63. DBN A.3.2-2:2009 A system of labor safety standards. Labor protection and industrial safety in construction. Basic provisions.
64. GKD 34.20.507-2003 Technical operation of power plants and networks. Rules.
65. RG-D.027.412-10 Procedures for maintenance and repairs of equipment as part of the systems important for safety of NPP units with VVER-1000. Part 1. Thermal and mechanical equipment.
66. NPAOP 0.00-1.01-07 Rules for erection and safe operation of hoisting cranes. Ukraine Committee for Labor Protection, 2007.
67. RG-D.0.05-412-10-02 Procedures for maintenance and repairs of equipment as part of the systems important for safety of NPP units with VVER-1000. Part 3. Electrical equipment.
68. RG-D.0.05-412-11-01 Procedures for maintenance and repairs of equipment as part of the systems important for safety of NPP units with VVER-1000. Part 2. Thermal automatic and measuring means, CAPCS equipment and technical means.
69. PNAE G-14-029-91 Safety rules for storage and transportation of nuclear fuel at atomic energy facilities.
70. SNiP 2.05.07-91 Industrial transport.
71. DBN B.2.3-4:2007 Motor roads.
72. DSTU B.2.3-29-2011 Obstruction clearance.
73. DBN B.2.3-19:2008 Transport facilities. 1520 mm railway tracks. Design standards.
74. Civil defence code of Ukraine, No 5403-VI of 02.10.2012.
75. Ukraine Law “On Higher Hazard Facilities” No 2245-III of 18.01.2001.
76. Safety rules for civil defence at enterprises, organizations, institutions and in hazardous areas. Order No 557 by Ukraine Ministry of Emergencies of 15.08.2007, registered by Ukraine Ministry of Justice 03.09.2007 under No 1006/14273.
77. A methodology for identification of potentially hazardous objects. Order No 98 by Ukraine Ministry of Emergencies of 20.03.2006, registered by Ukraine Ministry of Justice 03.09.2007 under No 268/12160.
78. Resolution No 956 by Ukraine Cabinet of Ministers of 11.07.2002 “On Identification and Declaration of Safety at Higher Hazard Facilities.
79. DK 019:2010 Classification of emergency situations.
80. Classification features of emergency situations. Order No 1400 by Ukraine Ministry of Emergencies of 12.12.2012, registered 03.01.2013 by Ukraine Ministry of Justice under No 40/22572.
81. GOST 12.1007-76 CCBT Harmful substances. Classification and general safety rules.
82. GOST 19433-88 Hazardous cargoes. Classification and marking.
83. DSTU 3868-99 Diesel fuel. Specifications.

84. GOST 10541-78 Motor oils – universal and for vehicles with carburetor engines. Specifications.
85. Provisions on the development of plans of localization and elimination of accident situations and accidents. Order No 122 by Ukraine State Committee for Supervision of Labor protection of 17.06.1999, registered 30.06.1999 by Ukraine Ministry of Justice under No 122.
86. Resolution No 368 by Ukraine Cabinet of Ministers “On Approval of a Procedure for Classification of Emergency Situations by Their Levels” of 24.03.2004.
87. Constitution of Ukraine, No 254k/96-VR, dated 28.06.1996.
88. Ukraine Law “On Fundamentals of National Security of Ukraine” No 964-IV of 19.06.2003.
89. Ukraine Law “On Environmental Protection” No 1264-XII of 25.06.1991.
90. DBN A.2.2-1-2003 Design. Composition and contents of materials on environmental impact assessment (EIA) for design and construction of enterprises, buildings and facilities. Ukraine State Committee for Construction, K., 2004 (with amendment No 1 of 14.09.2010).
91. Ukraine Law “On Assurance of Sanitary and Epidemic Welfare for People” No 4004-XII of 24.02.1994.
92. Ukraine Law “On Protection of Atmospheric Air” No 2707-XI of 16.10.1992.
93. Ukraine Law “On Nature Reserve Fund of Ukraine” No 2456-XII of 16.06.1992.
94. Ukraine Law “On Waste” No 187/98-VR of 05.03.1998.
95. Ukraine Law “On State Ecological Expertise” No 45/95-VR of 09.02.1995.
96. Ukraine Law “On Protection of People against Ionizing Radiation” No 15/98-VR of 14.01.1998.
97. Ukraine Law “On Legal Statues of the Territory Affected by Radioactive Contamination Caused by Chernobyl Disaster” No 795-XII of 28.02.1991.
98. Resolution No 808 by Ukraine Cabinet of Ministers of 28.08.2013 “On Approval of a List of Activities and Objects that Generate Higher Environmental Hazard”.
99. Ukraine State Committee for Land Resources. Order No 548 of 23.07.2010 “On Approval of Classification of Intended End-Uses of Land”.
100. DSP 173-96 State sanitary rules for planning and development of residential areas.
101. DGN 6.6.1-6.5.001-98 Safety radiation levels in Ukraine. State hygienic standards (NRBU-97).
102. DGN 6.6.1-6.5.061-2000 Safety radiation levels in Ukraine. Supplement: Radiation protection against potential radiation sources. State hygienic standards (NRBU-97/D2000).
103. DSP 173-96 State sanitary rules for planning and development of residential areas.
104. TEOI Centralized storage facility for spent fuel from Ukrainian NPPs’ VVER reactors, OJSC KIEP.
105. DBN B.1.2-5:2007 R&D support to construction projects.
106. DSTU-N B.1.1-27:2010 Protection against hazardous geological processes, harmful operational impacts and fire. Building climatology.
107. DSTU B.2.7-137:2008 Small wall porous concrete blocks. Specifications.
108. DBN A.2.2-3:2014 Composition and contents of design documentation on construction.
109. SP AS-88 Sanitary rules for design and operation of atomic plants, USSR Ministry of Health, 1988.
110. OSPU DSP 6.177-2005-09-02 Basic sanitary rules for assurance of radiation safety of Ukraine.
111. NP 306.2.141-2008 General provisions on safety of atomic plants. Order No 162 by Ukraine State Committee for Nuclear Energy, 19.11.2007.

112. Basic reference levels, release levels and action levels of radioactive contamination of exclusion zone objects. Introduced under Order No 940 by Chernobyl NPP State Joint Venture, 20.12.2013.
113. Resolution No 131-r by Ukraine Cabinet of Ministers of February 4, 2009 “On Approval of Technical and Economic Substantiation of Investment in construction of a centralized storage facility for spent fuel from domestic NPPs’ VVER reactors.
114. Ukraine Law “On Handling Spent Nuclear Fuel for Arrangement, Design and Construction of Centralized Storage Facility for Spent Fuel from Ukrainian NPPs’ VVER Reactors” No 4384-VI, 09.02.2012.
115. Comprehensive conclusion by Ukrgosstroiekspertiza State Enterprise No 84/54/288 of 26.08.2008.
116. Convention on environmental impact assessment in the transboundary context. UNO: Convention, an international document dated 25.02.1991.
117. Ukraine Law “On Ratification of Convention on Environmental Impact Assessment in the Transboundary Context No 534-XIV, 19.03.1999.
118. SNiP 2.09.02-85 Production buildings
119. SNiP 2.11.01-85 Storage buildings
120. DBN B.2.2-28:2010 Buildings of administrative and household purposes.
121. DBN B.2.5-67:2013 Heating, ventilation and air conditioning.
122. NPAOP 40.1-1.32-01 Rules of construction of electric installations. Electric equipment of special installations.
123. NP 306.6.124-2006 Rules of nuclear and radiation safety for transportation of radioactive materials (PBTRM-2006), State Committee for Atomic Energy Regulation, 2006.
124. PNAE G-5-006-87 Standards for design of earthquake-resistant nuclear power plants, USSR Academy of Energy Sciences.
125. HI-2074018 Report on the results from an analysis of MPC-31 and MPC-85 confinement. Report by Holtec International, 2009.
126. HI-2084001. CSFSF. Report on the results from a strength analysis of HI-STAR-190 and HI-STORM-190 systems. Rev. 2. Report by Holtec International, 2009.
127. Ukraine Law “On Higher-Risk Facilities” No 2245-III of 18.01.2001, with amendments as at 09.04.2014.
128. Ukraine Law “On State Budget of Ukraine for 2016” No 928-VIII of 25.12.2015.
129. Ukraine Law “On Protection of Cultural Heritage” No 1805-III of 08.06.2000.
130. Resolution No 557 by Ukraine Cabinet of Ministers of 27.04.2011 “On Approval of a Procedure for Designation of Construction Projects to Difficult Categories IV and V.
131. DSTU H B.1.2-16:2013 Determination of consequence (responsibility) class and difficulty category for construction projects.
132. Register of higher-risk facilities of Ukraine. Ukraine State Committee for Urban Supervision.
133. A methodology for assessment of damage from consequences of man-caused and natural emergencies, approved under Resolution No 175, 15.02.2002, by Ukraine Cabinet of Ministers, with amendments as of 04.06.2003.
134. RD 306.8.02/2.067-2003 Recommendations on the structure and contents of a report on analysis of safety of spent fuel storage facilities. Approved under Order by State Committee for Atomic Energy Regulation, 20.02.2003.
135. 1449NP-06-05 Assessment of CSFSF safety-important equipment for safety requirements. Holtec International, 2009.
136. HI-2084224. CSFSF. Design criteria for Phase 1. A list of design criteria for each item of equipment. Holtec International.
137. HI-2083996 Report on the results of the subcriticality analysis. Holtec International.

138. HI-2083902 Report on the results of thermal analyses for HI-STAR 190 UA, HI-STORM 190 UA and HI-TRAC 190 UA, Holtec International.
139. HI-2084001 Report on the results of strength analyses for HI-STAR 190 and HI-STORM 190 systems, Holtec International.
140. HI-2074018 Report on the results of an analysis for provision of MPC-31 and MPC-85 confinement, Holtec International.
141. HI-2084031 Report on the results of a radiation protection analysis, Holtec International.
142. HI-2073839 Report on compatibility of materials, Holtec International.
143. HI-2083899 Report on the results of a failure analysis, Holtec International.
144. S.V. Shirokov. Non-steady processes in nuclear reactors, Kiev 2002, 284 p.p.
145. A letter No 03-46/1197, 11.08.2015, from NAEK ENERGOATOM to OP Atomproektinzhiniring.
146. PBYA-06-08-88 Rules of nuclear safety for transportation of spent nuclear fuel. Approved by USSR State Committee for Atomic Energy, 14.09.1977.
147. PBYA-06-00-88 Basic rules of nuclear safety for reprocessing, storage and transport of nuclear hazardous fissile material, USSR State Committee for Atomic Energy, USSR Ministry of Atomic Energy, 1988.
148. Report on the research under contract No 349/14/571402 of 24.10.2014 “Assessment of safety in construction / installation activities as part of CSFSF project for VVER reactors from Ukrainian NPPs. Phase 1. “Assessment of safety in preparatory work including receipt of initial data on on the conditions on environmental components within the CSFSF project area”, IPB NPP, 2014.
149. Order No 248 by Ukraine Ministry of Health, 08.04.2014, on approval of the state standards and regulations “Hygienic Classification of Labor in Terms of Health Hazard of Production Environment and Labor Tension Factors”.
150. 571402.000.028.IDT00. Entry number KIEP 1993 of 13.08.15 Updating of data on radiation status of environmental components within the CSFSF project impact area. IPB NPP, 2015.
151. A procedure for calculation of current and potential irradiation doses for personnel during planning and design of work at the Shelter Facility, Ukraine Ministry of Health, 2004.
152. Rules of radiation safety for activities within the exclusion zone and compulsory resettlement zone. Approved by Ukraine Ministry of Health and Ministry of Emergencies under No 179/276.-K, 208.
153. Report on the research “Remote Effect of Fire in Forest and Grassland Ecosystems on the Physico-Chemical State of Radionuclides in the Exclusion Zone Biocenosis Components”, No 13/204n-99, State Enterprise CheNTSMI, 1999.
154. V.S. Davydchuk, R.F. Zarudnaya, S.V. Mikheli, M.F. Petrov, L.Yu. Sorokina, A.N. Tkachenko. Landscapes of the Chernobyl Zone and their Evaluation Based on the Conditions of Radionuclide Migration, Kiev, Naukova Dumka Publishing House, 1994.
155. A.I. Shcheglov. Biogeochemistry of technogenic radionuclides in forest ecosystems. From the materials of 10-year studies within the Chernobyl NPP accident impact area. M. Nauka Publishing House, 1999.
156. V.A. Kashparov, S.M. Lundin, A.M. Kadygrib, V.P. Protsak, S.Ye. Levchuk, V.I. Yoshchenko, V.A. Kashpur, N.N. Talerko. Radioecological and hygienic aspects of forest fires within the territory contaminated by Chernobyl accident// Hygiene and sanitation, No 1, 2001.
157. A.N. Nosovsky, B.Ya. Oskolkov, Ye.A. Ivanov, V.P. Udovichenko. Slavutich: Issues of radiation ecology //- Kiev, Vyshcha Shkola Publishing House, 2001.

158. IAEA, Safety Reports Series No 19. Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment. 2001.
159. Mills, M.T. (Nov. 204, 1987), “Modeling the Release and Dispersion of Toxic Combustion Products from Chemical Fires”, International Conference on Vapor Cloud Modeling, p.803 (Cambridge, MA).
160. Briggs, G.A.)Oct. 3, 1975), “Plume Rise Predictions,” Lectures on Air Pollution and Environmental Impact Analyses, Workshop Proceedings, p.p. 59-111 (American Meteorology Society, Boston, MA).
161. Hanna, S., G. Briggs and R. Hosker, Jr. (1982), Handbook on Atmospheric Diffusion, prepared for the Office of Health and Environmental Research, DOE/TIC-11223(DE82002045), pp. 68-71 (Office of Energy Research, U.S. Department of Energy).
162. NP.306.1.02/1.004-98. General provisions on safety to be assured as nuclear power plants and test nuclear reactors are decommissioned. Ukraine Ministry of Environmental Safety.
163. ANSI N14.5-1997. Test of transport packaging for tightness.
164. IAEA Safety Standards, Safety Requirements, No SSR – 6, “Regulations for the Safe Transport of Radioactive Material”, International Atomic Energy Agency, 2012 Edition.
165. U.S. Code of Federal Regulations Title 10 “Energy”, Chapter 1 “Nuclear Regulatory Commission”, Part 71 “Packaging and Transportation of Radioactive Material”, January 2006.
166. DBN B 1.2-2:2006 Ukraine State Building Regulations. A system of assurance reliability and safety for construction facilities. Loads and impacts. Design standards. Ukraine Ministry of Construction, 2006.
167. DBN B 1.1-12:2014 Ukraine State Building Regulations. Construction in Ukrainian seismic areas, Ukraine Ministry of Regional Construction, 2014.
168. DSTU-N B.1.1-27-2010 National Standard of Ukraine. Construction Climatology, Ukraine Ministry of Regional Construction, 2011.
169. Basic standard requirements and calculated characteristics of whirlwinds for Chernobyl NPP site. Approves by State Construction Committee 21.10.2002 under No 64.
170. Basic regulatory requirements and calculated characteristics for earthquakes for Chernobyl NPP site. A letter by Ukraine State Committee for Construction, No 3/19-19 of 08.07.2005, Attachment B.
171. ANSI N14.5-1997. Test of transport packaging for tightness.
172. IAEA Safety Standards, Safety Requirements, No SSR – 6, “Regulations for the Safe Transport of Radioactive Material”, International Atomic Energy Agency, 2012 Edition.
173. U.S. Code of Federal Regulations Title 10 “Energy”, Chapter 1 “Nuclear Regulatory Commission”, Part 71 “Packaging and Transportation of Radioactive Material”, January 2006.
174. Regulatory Guide 7.6, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels”, Revision 1, USNRC, Washington D.C., March 1978.
175. NUREG-0612, “Control of Heavy Loads and Nuclear Power Plants”, USNRC, Washington D.C., 1980.
176. Crane Manufacturers’ Association of America (CMAA), Specification #70, 1988.
177. DBN B.2.6-98:2009 Ukraine State Building Regulations. Constructions of buildings and facilities. Concrete and reinforced concrete structures. Basic provisions. Kiev, Ukraine Ministry of Regional Development and Construction, 2011.
178. DSTU B.2.6-156:2010 National Standard of Ukraine. Constructions of buildings and facilities. Concrete and reinforced concrete structures from heavy-weight concrete. Design regulations. Ukraine Ministry of Regional Construction, 2011.
179. GOST 12.1.004-91 SSBT Fire Safety. General Requirements.
180. NP 306.7.122-2006. Rules of accounting and control of nuclear materials. Ukraine State Committee for Atomic Regulation, 2006 (amendments of 2010).

181. Ukraine Law “Physical Protection of Nuclear Plants, Nuclear Materials, Radioactive Waste and Other Sources of Ionizing Radiation” with amendments as per the Law No 877-VII (877-18) of 13.03.2014, VVR, 2014, No 15.
182. Ukraine Law No 638-15 “On Fight against Terrorism” with amendments as per the Law No 649-VIII (649-19), 17.07.2015 VVR, 2015, No 37-38.
183. Recommendations on the physical nuclear safety for physical protection of nuclear material and nuclear plants, INFCIRC/225/Rev.5, IAEA, 2012.
184. Convention on physical protection of nuclear material. INFCIRC/274/Rev.1, IAEA, 1980.
185. Convention on physical protection of nuclear material and nuclear plants, with amendments as per the Law No 356-VI (356-17), 03.09.2008, VVR, 2008, No 48.